PRESIDENT, 1899–1901

From a bas-relief in bronze, modelled by Mr. G. W. DE SAULLES, *in the possession of the Iron and Steel Institute*

No. I [illegible]

THE JOURNAL

OF THE

IRON AND STEEL INSTITUTE

VOL. [illegible]

EDITED BY

BENNETT H. BROUGH

LONDON
E. & F. N. SPON, LIMITED, 125, STRAND
NEW YORK: SPON & CHAMBERLAIN, [illegible], CORTLANDT STREET
SOLD ALSO AT THE OFFICES OF THE INSTITUTE
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[illegible]

PRESIDENT, 1888–[illegible].

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No. 1 1901

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SECRETARY

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IRON AND STEEL INSTITUTE.

SECTION I.

MINUTES OF PROCEEDINGS.

ANNUAL GENERAL MEETING.

The ANNUAL GENERAL MEETING of the IRON AND STEEL INSTITUTE was held at the Institution of Civil Engineers, Great George Street, London, on Wednesday, May 8, 1901—Sir WILLIAM ROBERTS-AUSTEN, K.C.B., D.C.L., D.Sc., F.R.S., President, in the chair.

The PRESIDENT announced that the following Address had been laid before his Majesty the King:—

TO THE KING'S MOST EXCELLENT MAJESTY.

May it please Your Majesty,—

We, the President, Council, and Members of the Iron and Steel Institute, desire to be permitted to offer to your Majesty and to the other Members of the Royal Family the expression of our profound sympathy in the irreparable loss which has been sustained by your Majesty and by the Empire in the death of our revered Sovereign Queen Victoria.

The Iron and Steel Institute wishes to be permitted to pay a tribute of respect to the memory of a Sovereign who through a long reign, in which marked progress has been

made in the Metallurgical Arts, was unremitting in her devotion to the welfare of her subjects. The Iron and Steel Institute will keep in constant veneration the memory of her Majesty Queen Victoria, who showed her deep interest in the aims of the Society by being pleased to graciously accept the Bessemer Gold Medal, which was offered in commemoration of the progress made in the metallurgy of iron and steel during her Majesty's reign.

Thirteen years ago, your Majesty graciously accepted the Honorary Membership of our Institute, and we desire respectfully to offer to your Majesty the humble expression of our heartfelt congratulations and of our loyal homage and devotion.

Sealed with the seal of the Iron and Steel Institute, this thirtieth day of January 1901, in the presence of—

L. S.

W. C. ROBERTS-AUSTEN, *President.*
BENNETT H. BROUGH, *Secretary.*

The SECRETARY read the minutes of the last meeting, held at the house of the Société d'Encouragement pour l'Industrie Nationale, Paris, on September 18 and 19, 1900, which were confirmed and signed.

Mr. Alfred Campion and Mr. Robert Theodore Wilson were appointed scrutineers, and on the completion of their scrutiny reported that the following gentlemen had been duly elected as members of the Institute:—

NAME.	ADDRESS.	PROPOSERS.
Allender, Henry, *Bergrath*	Zolyombrézo, Gömörer Comität, Hungary	C. Ritter von Schwarz, Baron H. von Jüptner, H. G. Turner.
Arnold, John Oliver .	Sheffield University College, Sheffield	John E. Stead, Robert A. Hadfield, Sir William Roberts-Austen.
Böcking, Rudolf, *Königl. preussischer Commerzienrath*	Brebach, near Saarbrücken, Germany	C. Ritter von Schwarz, Baron H. von Jüptner, H. G. Turner.
Byers, William Lumsden	11 Norfolk Street, Sunderland	William Thackray, William Whitwell, Geo. Ainsworth.
Calderwood, James .	Maryland Steel Co., Sparrow's Point, Maryland, U.S.A.	Edward P. Martin, C. S. Martin, William Simons.

Name.	Address.	Proposers.
Camp, James M'Intyre	Duquesne, Pennsylvania, U.S.A.	Thomas Morrison, E. Fred. Wood, Guy R. Johnson.
Clark, William . . .	23 Royal Exchange Square, Glasgow	Fred. W. Paul, James Riley, Nicholas K. Turnbull.
Cook, George Norcliffe	13 Blyth Road, Worksop, Notts	Lewis J. Firth, J. Rossiter Hoyle, Harry Marsden.
Cook, Samuel . . .	Albert Works, Bury, Lancashire	Geo. A. Shipman, William F. Beardshaw, John W. Shipman.
Crockard, Frank Hearne	Wheeling, West Virginia, U.S.A.	Julian Kennedy, Samuel T. Wellman, William Garrett, W. H. Bradley.
Cumming, Henry Leslie	Bank Place, Melbourne, Australia	George Hatton, Arthur Cooper, John H. Darby.
Custodis, Josephus Charles	St. Marie's Chambers, 6A Norfolk Row, Sheffield	R. M. Daelen, E. Schrödter, Ernest F. Lange.
David, Hezekiah . .	Pencoed, near Bridgend, Glamorganshire	David Richards, Fred. F. Card, William Davis.
Dupré, Frederic . .	93 Billiter Buildings, London, E.C.	Edwd. Riley, Eugène Poulaine, Christmas Evans.
Foster, William James	Darlaston Green Iron Works, Darlaston, Staffordshire	W. Moore, Edward Richards, Walter Macfarlane.
Funke, Hermann Frank Richard	74 Victoria Street, Sheffield	Joseph Jones, Robert Colver, H. Wedding.
Goldschmidt, Hans, Ph.D.	Bismarckstrasse, 98, Essen a/d Ruhr, Germany	Ernest F. Lange, Sir William Roberts-Austen, John E. Stead.
Henricot, Paul . . .	Court-St.-Etienne, Belgium	Maurice Magery, Emil Schrödter, Jules Magery.
Hoy, Henry Albert .	Lancashire and Yorkshire Ry. Co.'s Works, Horwich, Lancashire	Henry Webb, J. Scarisbrick Walker, Ernest F. Lange.
Hughes, Theophilus Vaughan, Assoc. R.S.M., F.I.C., F.C.S.	Norwich Union Chambers, Birmingham	Sir William Roberts-Austen, H. G. Graves, Godfrey Melland.
Jackson, John . . .	3 Hallside, Newton, Glasgow	Geo. J. Snelus, Alfred Campion, Fred W. Paul.
James, Christopher Wm., M.I.Mech.E.	Wellhouse Foundry, Leeds	Edwd. P. Martin, Alfred Bowen, William Simons.
Kirkip, William . .	Luchana, Bilbao, Spain	Sir David Dale, Geo. Ainsworth, E. Scott.
Lodin, Arthur . . .	16 Rue Desbordes-Valmore, Paris	Sir William Roberts-Austen, John E. Stead, Percy C. Gilchrist.
Mackenzie, Thomas Brown	342 Duke Street, Glasgow	John Colville, David Colville, Sir William Arrol.
Marcoartu, *His Excellency Don* Arturo de, M.Inst.C.E.	Madrid	Sir Bernhard Samuelson, Edwd. P. Martin, Sir David Dale.
Moorwood, Francis Colin	260 Barnsley Road, Sheffield	John D. Ellis, James Duffield, C. Stanley Martin.
Morton, Benjamin Kirk	West Street Lane, Sheffield	Sir Benjamin Hingley, Percy W. Lee, George B. Hingley

Name.	Address.	Proposers.
Perry, William Henry	14 Westbourne Street, Stockton-on-Tees	William Whitwell, W. Fry Whitwell, Sir William Roberts-Austen.
Robinson, Charles Snelling, B.Sc.	720 Boston Building, Denver, Colorado, U.S.A.	Julian A. Kebler, Robert Forsyth, Theodore W. Robinson.
Rosenhain, Walter, B.A.	Chance's Works, Birmingham	Sir William Roberts-Austen, Jas. A. Ewing, John E. Stead.
Round, J. Lawrence .	Court Oak, Harborne	Sir Benjamin Hingley, G. H. Claughton, Joseph H. Pearson.
Rylands, William Peter	Dingle Bank, Lymm, Cheshire	W. H. Bleckly, Sir Bernhard Samuelson, Arthur Cooper.
Solacroup, Emile . .	56 Boulevard Malesherbes, Paris	Henry Chapman, Sir William Roberts-Austen, Sir F. A. Abel.
Tatnall, James E. . .	Empire Building, Pittsburg, Pennsylvania, U.S.A.	Horace W. Lash, Samuel T. Wellman, William Garrett.
Theisen, Eduard . .	Baden - Baden, Germany	David Evans, John E. Stead, Arthur Cooper.
Wiles, Edwin L. . .	Wheeling, West Virginia, U.S.A.	Julian Kennedy, Samuel T. Wellman, Wm. Garrett, W. H. Bradley.

The following Report of the Council upon the proceedings of the Institute during the year 1900 was then submitted:—

REPORT OF COUNCIL.

At this thirty-second Annual General Meeting of the Iron and Steel Institute, the Council present to the members their Report on the proceedings of the Institute during the year 1900, and are glad to note that during that year the Institute has made satisfactory progress.

The Roll of the Institute.

During the year under review there have been added to the register 97 names, a number somewhat in excess of the average of the previous six years. The number of members on the roll of the Institute on December 31, 1900, was—

Honorary members	10
Life members	16
Ordinary members	1618
Total	1644

To the list of Honorary Members the names of Mr. Gustave Canet, President of the Society of Civil Engineers of France, and of Mr. Adrien de Montgolfier, Director-General of the St. Chamond Works, have been added during the year.

The Council have to congratulate several members of the Institute who have had high distinctions conferred upon them. Mr. Victor Cavendish, M.P., Member of Council, has been appointed Treasurer of the Royal Household. Sir Frederick A. Abel, Bart., Past-President, has been created a Knight Grand Cross of the Royal Victorian Order. Queen Victoria conferred the dignity of a baronetcy on Sir Thomas Wrightson, M.P., Sir Arthur T. Lawson, and Sir John Aird, M.P. Mr. E. Windsor Richards, Past-President, has been appointed by the King of the Belgians a Knight Commander of the Order of Leopold, and by the Queen Regent of Spain, a Knight Grand Cross of the Royal Order of Isabella the Catholic. The German Emperor has appointed Mr. F. A. Krupp a Privy Councillor with the title of Excellency, and has conferred the Order of the Red Eagle upon Mr. Emil Guilleaume, Mr. Jules Magery, and Mr. T. von Guilleaume. The Emperor of Austria

has conferred upon Mr. F. A. Krupp the Grand Cross of the Franz Joseph Order. Mr. E. J. Ljungberg, General Manager of the Stora Kopparbergs Berslags Aktiebolag, whom the Council congratulated on the celebration of the 25th anniversary in the service of that Company, has been promoted to the rank of Knight Commander (1st Class) of the Royal Wasa Order, and has been elected a member of the Swedish Academy of Sciences. Mr. Pierre Arbel and Mr. H. A. Brustlein have been promoted to the dignity of Officer of the Legion of Honour, and Professor H. M. Howe has been created a Knight of the same Order. Mr. F. H. Kockum of Malmö has been created a Knight of the Royal Order of the Polar Star, and Mr. E. Schrödter has been created a Knight of the Royal Order of Isabella the Catholic. The honorary degree of Doctor of Science has been conferred by the Victoria University upon Sir William Roberts-Austen, K.C.B., President, and honorary degrees have been conferred by the University of Cambridge on Sir Benjamin Baker, by Yale College upon Mr. Julian Kennedy, and by the Dresden Technical College upon Mr. Frederick Siemens. Among the honours that have been bestowed upon the members of the Institute, the Council note that Mr. John G. A. Leishman has been appointed United States Minister to Turkey, Sir W. T. Lewis, Bart., has been elected President of the Institution of Mining Engineers, and Mr. S. T. Wellman, President of the American Society of Mechanical Engineers. The Paris Academy of Sciences has awarded the Vaillant Prize to Mr. F. Osmond for his researches on metals and alloys, the Swedish Technological Society has awarded the Polhem Prize to Mr. J. A. Brinell, and the Institution of Civil Engineers has awarded a George Stephenson Medal and a Telford Premium to Sir Lowthian Bell, Bart., Past-President. On the occasion of the Paris meeting of the Institute, Sir William Roberts-Austen, President, was elected an Honorary Member of the French Society of Civil Engineers.

During the year 1900 the Institute has suffered great losses by the death of the following thirty-six members:—

Armstrong, Right Hon. Lord (Newcastle-on-Tyne)	December 27.
Armstrong, George Frederick (Edinburgh)	November 16.
Albright, Arthur (Birmingham)	July 3.
Bruce, William Duff (London)	April 28.
Cherrie, James MaCullum (Glasgow)	March 9.
Craven, John (Manchester)	June 12.
Craven, Joseph (Sheffield)	December.

Dawson, Bernard (Malvern Link)	March 3.
Day, Richard (Bridlington Quay)	August 16.
Downing, Samuel (Birmingham)	August 11.
Edge, John Harris (Shifnal)	October.
Fletcher, William (Cockermouth)	August 6.
Hill, Alfred (Coatham)	April.
Hodgson, John Lee (Stockport)	January 31.
Jeffreys, John Robert (Ipswich)	September 12.
Jordan, Samson (Paris)	February 24.
Lindberg, Carl Carlson (Laxå)	February 12.
McCowan, William (Whitehaven)	March 5.
Morris, Claude John (Buxton)	October 8.
Parkes, Henry Persehouse (Tipton)	May 17.
Pidgeon, Daniel (Banbury)	March 13.
Polonceau, Gustave Ernest (Paris)	March 3.
Rider, Henry Hyam (Rotherham)	March.
Round, Benjamin (Harborne)	October 22.
Ryland, William (Sheffield)	October 11.
Sartoris, Herbert (Kettering)	August 30.
Saunders, James (Wolverhampton)	April 13.
Schmitz, Albert (Essen)	June 19.
Seebeck, Leopold (London)	July 16.
Smethurst, John (Wigan)	March.
Stewart, Peter (Glasgow)	July 3.
Swan, John George (Middlesbrough)	December 23.
Tosh, Edmund George (Ulverston)	April 22.
Tylden-Wright, Charles (Nottingham)	August 8.
Valentine, Charles J. (London)	November.
Vaughan, Thomas (Middlesbrough)	November 30.

The following deaths of members occurred in 1899, but were not noted in the Council Report for that year :—

Jones, James (Swansea)	November 16.
Pattison, John (Naples)	Autumn.

Of the deceased members, Lord Armstrong, whose many inventions earned for his name a world-wide fame, was an original member of the Institute and frequently contributed to the discussions. He was awarded the Bessemer Gold Medal in 1891. Professor Jordan, the gr metallurgist, contributed a paper to the Institute's Proceedi

and in 1889, and was also a frequent contributor to the discussion of papers read. He was an energetic member of the Reception Committees on the occasion of the Paris meetings of the Institute in 1878 and in 1889. Mr. Lindberg was one of the five members of the Executive Committee that arranged the reception of the Institute in Stockholm in 1898, and he hospitably entertained the members of the Western Excursion at Laxå Works. Mr. Polonceau took an active part in organising the Paris meeting of the Institute in 1889. Professor G. F. Armstrong acted as Local Honorary Secretary in connection with the Institute's meeting in Edinburgh in 1888. Particulars of the professional careers of the deceased members will be found in the obituary notices published in the Journal of the Institute.

In consequence of non-payment of subscriptions the names of eight members have been removed from the list, and there have been twenty resignations of membership.

Finance.

The Statement of Accounts for the year 1900, verified by the Auditors, is now submitted to the members by the Honorary Treasurer. It will be observed that the income for the year amounted to £4157, and the expenditure to £3771.

The corresponding figures for recent years were as follows:—

	Income.			Expenditure.		
	£	s.	d.	£	s.	d.
1899 . . .	4322	10	4	3606	16	6
1898 . . .	3985	13	7	3989	16	8
1897 . . .	3937	5	8	3207	10	3
1896 . . .	3891	12	11	4338	14	11

Owing to the incorporation of the Institute under a Royal Charter, the invested funds have been transferred from the names of the Trustees to that of the Institute, and the Council take this opportunity of thanking the Trustees, Sir Joseph Pease, Bart., M.P., the Right Hon. Lord Wimborne, and Sir David Dale, Bart., for their long and valuable services to the Institute. The incorporation of the Institute rendered it necessary for a Common Seal to be provided, and Mr. Pinches has engraved the dies for one under the direction of the Council. It bears the head of the late Duke of Devonshire, the Institute's first President. All documents to which the Common Seal has to be affixed are now passed and sealed in Council.

Meetings.

During the year under review two meetings were held as usual. The Annual Meeting on May 9th was held at the Institution of Civil Engineers, and the constant courtesy of that distinguished body in providing accommodation demands grateful acknowledgment.

The Autumn Meeting, held, for the third time since the foundation of the Institute, in Paris, was largely attended, and brilliantly successful. A very influential Reception Committee was formed, with Mr. Robert de Wendel as President. Lavish hospitality was dispensed by the Comité des Forges, by the Société d'Encouragement pour l'Industrie Nationale, by the Minister of Public Works, by the President of the Municipal Council of Paris, by Mr. Eugene Schneider, by Mr. G. Canet, by Mr. H. de Wendel, by Mr. A. de Montgolfier, by the Chairman and Directors of the Société des Métaux, by Colonel Jekyll, and by Mr. Henry Chapman, who again placed his Paris offices at the disposal of his fellow-members; and the grateful thanks of the members were accorded for the cordiality of the reception given to the Institute. The excursions in connection with the meeting were most instructive, and have been described at length in the Journal of the Institute.

To Mr. Henry Vaslin, the local Honorary Secretary, whose ability and indefatigable energy contributed so largely to the success of the meeting, the Council have expressed on behalf of the members their sense of indebtedness by presenting to him a piece of statuary in bronze with a suitable inscription, in appreciation of his valuable services in carrying out the necessary arrangements for the meeting. They also forwarded to Mr. Robert de Wendel, the President of the Committee, an illuminated address of thanks, and specially bound volumes of the Journal containing the report of the meeting were presented to the members of the Reception Committee. Mr. Gustave Canet, President of the Society of Civil Engineers of France, and Mr. A. de Montgolfier, Director-General of the St. Chamond Works, were elected Honorary Members of the Institute; the Council considering that a fitting opportunity was afforded of marking their appreciation of the great services rendered by these gentlemen to the metallurgy of iron, and of the many benefits conferred by them on the Iron and Steel Institute. In addition to the President's address, read at the Paris meeting, the papers contributed to the Institute's Proceedings during the year were as follows:—

1. On the Use of Fluid Metal in the Open-Hearth Furnace. By J. Riley (Vice-President).
2. On the Open-Hearth Continuous Steel Process. By B. Talbot.
3. On a Blowing-Engine worked by Blast-Furnace Gas. By A. Greiner (Member of Council).
4. On the Manufacture and Application of Water-Gas. By C. Dellwik.
5. On the Utilisation of Blast-Furnace Slag. By C. von Schwarz.
6. On the Equalisation of the Varying Temperatures of Hot-Blast. By L. F. Gjers and J. H. Harrison.
7. On Ingots for Gun Tubes and Propeller Shafts. By F. J. R. Carulla.
8. On the Manganese Ores of Brazil. By H. K. Scott.
9. On the Theory of Solution of Iron and Steel. By Baron H. von Jüptner.
10. On the Development of the Iron and Steel Industries in France since 1889. By H. Pinget.
11. On Iron and Phosphorus. By J. E. Stead (Member of Council).
12. On Iron and Steel at the Paris Exhibition. By Professor H. Bauerman.
13. On a New Method of Producing High Temperatures. By E. F. S. Lange.
14. On American Methods of Testing Iron and Steel. By A. L. Colby.
15. On the Action of Aluminium on the Carbon in Cast Iron. By Godfrey Melland and H. W. Waldron.
16. On Rolling-Mills. By Louis Katona.
17. On the Constitution of Slags. By Baron H. von Jüptner.
18. On Iron and Steel from the Point of View of the "Phase-Doctrine." By Professor Bakhuis-Roozeboom.
19. On the Present Position of the Solution Theory of Carburised Iron. By A. Stansfield.

The Annual Dinner of the members of the Institute was held on May 9th, at the Hotel Cecil. The chair was occupied by the President, and amongst the noblemen and gentlemen present were the First Lord of the Admiralty, Lord Kelvin, Lord Strathcona, Admiral Sir John Dalrymple-Hay, General F. T. Lloyd, Sir Courtenay Boyle, Sir Benjamin Baker, the Presidents of many of the kindred societies, most of the members of Council, and a large number of members and their friends. The Institute also gave a dinner at the Hotel Continental

in Paris on September 19th, to which the members of the Local Reception Committee and other distinguished French metallurgists were invited. The chair was occupied by the President, and about 250 members and their friends were present.

For the Autumn Meeting of the present year the Institute has accepted an invitation to meet in the city of Glasgow on September 3rd to 6th, simultaneously with the holding of an International Engineering Congress, of Section V. (iron and steel), of which the Iron and Steel Institute has undertaken to take charge. Remembering the great benefits derived from the previous highly successful meetings of the Institute in Glasgow in 1872 and in 1885, the Council look forward with confidence to a renewal of past experience.

Publications.

Two volumes of the Journal of the Institute have been published, containing together 1173 pages of letterpress, 39 plates, and illustrations in the text. In addition to the papers read before the Institute, and the discussions and correspondence relating to them, those volumes contain abstracts of 1507 papers relating to iron and steel and kindred subjects published in other home and foreign Journals and Transactions. In view of the frequent applications made to the Institute for detailed particulars of the methods and appliances referred to in the abstracts, there can be no doubt that they constitute a useful feature of the Journal, and in order to enhance their utility, the Council has instructed the Secretary to compile a General Index to the Journal of the Institute up to the end of 1900, forming a continuation to the General Indexes already published. The preparation of the Index is making satisfactory progress, and the volume will, it is hoped, be issued to the members during the year.

Library and Offices.

Numerous presentations to the Library have been made, a list of which is given in the Journal of the Institute. Chief among these, the Council have to record their thanks to Mr. Gustave Eiffel for two handsome folio volumes, containing a detailed description of the tower that bears his name. Members who have published works valuable for reference, or pamphlets on subjects relating to iron and steel, of which

they could present copies, are reminded that such contributions to the Library are highly acceptable for permanent preservation. Additional bookshelf accommodation has been provided to meet the growth of the Library.

The additions to the collection of portraits include a portrait of Mr. Henri de Wendel, Bessemer Gold Medallist, presented by that gentleman. The collection of portraits has been enriched by the presentation by Messrs. Maull & Fox of a number of platinotype photographs of members of the Institute.

The Office accommodation has during the past year received the attention of the Council. An additional room has been acquired, and electric light has been installed.

The appointment of Chief Clerk to the Institute, rendered vacant by the resignation of Mr. C. McDermid, who had, during his tenure of office, invariably carried out his duties in a conscientious and energetic manner, has been filled by the appointment of Mr. G. C. Lloyd, chief assistant to Messrs. Jeremiah Head & Sons of Westminster.

Bessemer Gold Medal.

The Bessemer Gold Medal for 1900 was presented to Mr. Henri de Wendel, in recognition of his great services to the metallurgy of iron, and of the active part taken by him in the development of the phosphoric iron ore resources of French and German Lorraine.

Appointment of Representatives.

During the year the President and Sir Frederick Abel, Bart., Past-President, continued to represent the Institute on the governing body of the National Physical Laboratory, and the President continued to represent the Institute on that of the Imperial Institute.

Owing to his removal from Scotland, Mr. James Riley, Vice-President, resigned the position as the Institute's Scottish representative on Lloyds' Technical Sub-Committee, and Mr. William Beardmore, Member of Council, was appointed to fill the position for the unexpired portion of Mr. Riley's term of office. The Institute was represented at the International Metallurgical Congress, held at Paris on June 18th to 23rd, by the President, who was appointed Honorary President of that Congress, and by the Secretary. The Institute was also represented at the International Congress on Methods of Testing, held at Paris on

July 9th to 16th, and at the International Geological Congress, held at Paris on August 17th to 28th.

On the occasion of the celebration of the fiftieth anniversary of the Geological Survey of Austria on June 9th, a congratulatory address was presented on behalf of the Institute. The Institute was also represented on the occasion of the reception to kindred societies by the French Society of Engineers, on June 15th to 20th, by the President, Mr. G. J. Snelus, Vice-President, and the Secretary.

Paris Exhibition.

The Iron and Steel Institute participated in the Paris Exhibition by showing in the gallery of Class 64 the historical collection of specimens of Bessemer steel, dating back to June 1856, presented by the late Sir Henry Bessemer to the Institute. A considerable number of members took part in the work of the Exhibition. The President of the British Royal Commission was His Majesty the King, Honorary Member of the Iron and Steel Institute. Among the Royal Commissioners were the following members of the Iron and Steel Institute:—The Duke of Devonshire, K.G.; Sir James Kitson, Bart., M.P., Past-President; Sir E. H. Carbutt, Bart., Member of Council; Sir F. A. Abel, Bart., K.C.B., Past-President; Mr. E. Windsor Richards, Past-President; and Mr. S. E. Howell. Among the British Jurors appointed to the International Jury were the following members of the Institute:—Class 20, engines, Mr. G. Cawley; Class 21, general machinery, Mr. W. H. Massey; Class 22, machine tools, Sir W. T. Lewis, Bart., Vice-President; Class 64, metallurgy, Sir William Roberts-Austen, K.C.B., President; Class 65, metal-working, Mr. Bennett H. Brough, Secretary. The following members of the Institute also served on the International Jury:—Mr. P. Arbel, France; Mr. H. A. Brustlein, France; Mr. A. L. Colby, United States; Mr. E. Disdier, Spain; Professor H. M. Howe, United States; Mr. L. Lévy, France; Mr. D. Tschernoff, Russia; and Mr. A. Wahlberg, Sweden.

The Andrew Carnegie Research Scholarship.

The President, Sir William Roberts-Austen, announced at the Paris meeting that he had received a communication from Mr. Andrew Carnegie, Vice-President, announcing his intention of generously presenting to the Institute the sum of £6500, to be devoted to the

promotion of metallurgical research. Mr. Carnegie subsequently forwarded to the Institute thirty-two one-thousand-dollar Pittsburg, Bessemer, and Lake Erie Railroad Company 5 per cent. debenture bonds for the purpose. It has been decided that a Gold Medal and a Research Scholarship or Scholarships will be awarded annually, irrespective of sex or nationality, on the recommendation of the Council of the Institute. Candidates, who must be under thirty-five years of age, must apply before the end of April, on a special form, to the Secretary of the Institute.

The object of this scheme of scholarships is not to facilitate ordinary collegiate studies, but to enable students who have passed through a college curriculum, or have been trained in industrial establishments, to conduct researches in the metallurgy of iron and steel and allied subjects, with a view to aiding its advance or its application to industry. The National Physical Laboratory, on the governing body of which the Iron and Steel Institute is represented, would for many reasons be a suitable place in which such a research could be carried out. There is, however, no restriction as to the place of research which may be selected, whether university, technical school, or works, provided that it be properly equipped for the prosecution of metallurgical investigation. The appointment to the Scholarship shall be for one year, but the Council may at their discretion renew the Scholarship for a further period instead of proceeding to a new election. The results of the research shall be communicated to the Iron and Steel Institute in the form of a paper to be submitted to the annual general meeting of members, and if the Council consider the paper to be of sufficient merit, the Andrew Carnegie Gold Medal shall be awarded to its author. Should the paper in any year not be of sufficient merit, the medal will not be awarded in that year.

Retiring Members of Council.

The retiring Members of Council are:—

Vice-Presidents: Sir J. G. N. Alleyne, Bart.; Mr. G. J. Snelus, F.R.S.; Mr. James Riley.

Members of Council: Mr. J. D. Ellis; Mr. R. A. Hadfield; Sir B. Hingley, Bart.; Mr. William Beardmore; Mr. David Evans.

As no other members were nominated up to one month previous to this meeting, in response to the announcement made at the Paris meeting, these gentlemen, who are all eligible, are presented for re-election.

The Council having elected Mr. William Whitwell, Honorary Treasurer, to succeed Sir William Roberts-Austen as President, have chosen Mr. W. H. Bleckly, Vice-President, who has served on the Council for twenty years, as Honorary Treasurer, to fill the vacancy caused by Mr. Whitwell's election to the Presidency.

The Honorary Treasurer (Mr. William Whitwell) then read the Statement of Accounts for the year 1900 (pp. 16 and 17). Commenting upon the accounts, he pointed out that the income was slightly lower than it had been in the previous year, the difference being due to a falling off in the amount received for life-compositions. The amount received for annual subscriptions was, however, greater. Owing to the increased income-tax the yield of interest on investments was less. The expenditure was a little higher than in 1899. The increase was due chiefly to the cost of exhibiting at Paris, to the installation of the electric light, furnishing and decorating the Institute offices, and to the extra large size of the two volumes of the Journal published during the year. The low expenditure in connection with the Paris meeting was eminently satisfactory. The meeting was very largely attended, and yet the cost was considerably less than that of the previous meeting in Paris in 1889.

THE IRON AND STEEL INSTITUTE.

ACCOUNT OF INCOME AND EXPENDITURE FOR THE YEAR ENDED DECEMBER 31, 1900.

INCOME.

	£	s.	d.
To Entrance Fees	£ 197	8	0
,, Annual Subscriptions	3,380	8	0
,, Life-Compositions	63	0	0
,, Journal Sales	175	4	3
,, Interest on Investments	306	0	6
,, Bessemer Medal Fund Interest	15	8	4
,, Sundry Receipts	10	13	6
	£4,157	2	7

EXPENDITURE.

	£	s.	d.	£	s.	d.
By Salaries				£1,168	6	2
,, Office Rent, Cleaning, &c.				410	9	0
,, Library Books and Binding				49	10	4
,, Office Furniture				160	5	10
,, Annual Meeting (London)				50	19	0
,, Autumn Meeting (Paris)				260	0	10
,, Journal Publishing Expenses:—						
Printing	£846	12	6			
Abstracts	177	2	0			
Translation of Papers	58	10	6			
Postage	88	1	7			
				1,170	6	7
,, Postage and Receipt Stamps				100	9	7
,, Printing and Stationery				224	18	8
,, Insurance				1	15	0
,, Bessemer Medal				15	5	0
,, Corporation Duty				15	10	9
,, Sundry Payments (including Expenses of Paris Exhibit)				131	11	3
,, Auditor's Fee				12	12	0
				3,771	19	7
,, Balance, being excess of Income over Expenditure				385	3	0
				£4,157	2	7

LIABILITIES.

To Sundry Creditors :—		
,, Printing Journal	£445 8 7	
,, Journal Postage	47 8 1	
,, Journal Translations	36 4 0	
,, Journal Abstracts	25 0 0	
,, Library Books and Binding	8 13 10	
,, Printing and Stationery	16 12 7	
,, Office Furniture	51 15 0	
,, Sundry Expenses (Paris Exhibit)	12 12 9	
,, Rent	102 1 8	
		£745 16 6
,, Subscriptions in advance		42 0 0
,, Iron and Steel Institute Capital Account at 1st January 1900	£361 10 3	
Add Excess of Income over Expenditure transferred from Income and Expenditure Account	385 3 0	
		746 13 3
		£1,534 9 9

ASSETS.

By Subscriptions in arrear for 1900, since received	£107 2 0	
,, Subscriptions in arrear for 1899, since received	10 10 0	
		£117 12 0
,, Interest on Investments accrued, due at 31st December 1900		155 0 5
,, Journal Sales, since received		84 7 0
,, Cash at Bank		1,040 18 5
,, Do. in Secretary's hands		136 11 11
		£1,534 9 9

INVESTED FUNDS OF THE INSTITUTE.

£3,744 North-Eastern Railway 4 per cent. Preference Stock, purchased at a cost of	£4,297 6 7
£788 North-Eastern Railway 4 per cent. Guaranteed Stock, purchased at a cost of	1,008 14 0
"B" Annuity £79 4s. 5d. Scinde, Punjaub, and Delhi Railway expiring 1958 with a Sinking Fund to replace the amount of Stock, purchased at a cost of	1,999 0 7
"B" Annuity of £50, 1s. 8d. Great Indian Peninsular Railway expiring 1948 with a Sinking Fund to replace the amount of Stock, purchased at a cost of	1,267 6 0
£700 Middlesbrough Corporation Waterworks 3½ per cent. Debenture Stock, purchased at a cost of	751 2 0
	£9,323 9 2

(Signed) WILLIAM WHITWELL, *Hon. Treasurer.*
BENNETT H. BROUGH, *Secretary.*

I have examined the above Accounts with the Books and Vouchers of the Institute, and certify them to be correct. I have also verified the Balance of the Bankers' Account, and examined the Securities for the Invested Funds as shown above.

(Signed) W. B. KEEN,
Chartered Accountant.

3 Church Court, Old Jewry, E.C.

BESSEMER MEDAL FUND.

£534 London and North-Western Railway 3 per cent. Debenture Stock.

The PRESIDENT said that in the Report there was one very prominent feature to which he must call attention—namely, his announcement at the Paris meeting that he had received a communication from Mr. Andrew Carnegie announcing his intention of generously presenting to the Institute the sum of £6500 to be devoted to the promotion of metallurgical research. It was subsequently decided that a gold medal and a research scholarship or scholarships should be awarded annually, irrespective of sex or nationality, on the recommendation of the Council of the Institute. The candidates must, in accordance with Mr. Carnegie's wishes, be under thirty-five years of age, and must apply before the end of April in a special form to the Secretary of the Institute. The Council, in accordance with the most munificent gift made by Mr. Andrew Carnegie, had made its first award this year. In view of the wishes of Mr. Carnegie, and of the international character of the gift, it had been decided that it should not only be given to Englishmen, but in turn to men of all nations of the earth. They had accordingly given one-third to Dr. Mathews, a distinguished American worker, one who would continue his work under Professor Howe in America. Another scholarship had been given to Mr. Julius Goldberg, an Austrian, who had done very good work; and the other third to Dr. A. Stansfield, to whom the Institute was already indebted for some valuable papers. It had been a question of some difficulty as to who among the many distinguished Englishmen should receive the third share, but it was finally agreed to give it to Dr. Stansfield, the eldest of the other candidates who had presented themselves.

He had also the great pleasure of being able to say that Mr. Andrew Carnegie, not content with the munificent gift he had already given, had expressed his intention to double that gift.

He then formally moved the adoption of the Report and Statement of Accounts.

Mr. H. G. TURNER said he had great pleasure in seconding the motion that the Report of the Council and Statement of Accounts be adopted. He would not detain the meeting for any length of time, but he wished to draw attention to one matter which had always been of very great interest to him—namely, the reference

in the Report to the publications of the past year. In 1898 he had the pleasure of drawing attention to the very efficient way in which the library and the publications were managed by the Council and the Staff. He now desired to reiterate his opinion, and also the opinion of all present, that that department of the business was managed in a most efficient and proper way. He was glad to see that the Council had instructed the Secretary to prepare a continuation of the index. There was to be a continuation of the index brought up to date, and that would be a very material benefit to all who wished to search the volumes. It had been of the very greatest importance to him, not only from a scientific, but also from a business point of view. They could not do better than congratulate themselves that the Council and Secretary had taken such a great interest in the matter, and intended to pursue the policy of keeping up the publications to the best possible standard.

The resolution was carried unanimously.

Mr. F. W. Harbord said he felt very great pleasure in rising to propose that the very best thanks of this meeting be given to the retiring President for the way in which he had entirely devoted his energies to the interests of the Institute throughout the past two years. During that period several things had occurred which would always be memorable in the history of the Institute. First, there was the Presidential Address, which had dealt so exhaustively with metallurgical progress in connection with iron and steel, and the sympathetic way he had dealt with the various work done by past Presidents was most highly appreciated by every member of the Institute. The suggestion that her late Majesty Queen Victoria should be asked to accept the Bessemer Medal was largely due to their retiring President, and its gracious acceptance not only emphasised the vast progress made in the great iron and steel industries, but was the highest honour which could be bestowed upon the Institute. There was also the visit to Paris, which was made under exceptional difficulties, the great success of which everybody would admit was largely due to the unfailing courtesy and untiring energy of the gentleman about to vacate the presidential chair.

His review of the work done in the past ... was a masterpiece in its way, and a ... greatest value to all persons interested in ...

Another matter which was worthy of ... ment of the President as a member ... especially selected to inquire into the ... of iron and steel for ordnance work. ... tenure of office of the retiring President ... able for the munificent gift which Mr. Car... Institute through him, a gift which ... a new era in metallurgical research, ... members of the Institute to carry on ... not only be of value to all connected ... with the highest class of research ... world. He begged leave to propose ... of the meeting be given to the retiri... in the chair during the past two yea...

Mr. CHARLES LOWTHIAN BELL ... motion, which he had great pleasu... words of his to bring it more fo... the members, as it had been so ably ...

The resolution was carried by ...

The PRESIDENT said that, hav... of work to be got through, he w... The moment had come when ... mitted to him, and the period ... delightful one for him. It ... episode in his life to be a Pr... support of the Council, and of ... received throughout, and woul... had said, there had been ... with gratification. But all ... by the one sad memory that ... Queen Victoria they had los... the "Age of Steel" had been ... more for him to do—nam...

would be known eventually. He hoped he assist in the future in rolling away some ignorance. He thanked the President, as Institute, for having conferred that great honour which he would never forget.

then delivered his inaugural address.

to award him the Bessemer Medal for his researches. These researches had been entirely a labour of love. It was a great reward when, by patient working, some hidden truth which had been concealed for generations was established. Metallurgical research could not be done without the opportunity, and he remembered with the greatest gratitude the encouragement and opportunity in original research which had been given him when he first entered the Middlesbrough works as an analytical chemist. At that time Mr. Edward Williams was the general manager. Mr. Williams did not appoint him to wash bottles and to make analyses only—that was a minor part of his work—but presented him with innumerable problems to solve. Some he was happy to say he had solved, but others still needed more research. He must not forget also that the work he had done had not been his own only. In seeking after practical truth, one man could do very little alone, and what he had done was to solicit and obtain the co-operation of an army of friends. There was no iron manufacturer and no steel manufacturer in this country to whom he had applied who had not said readily, "We will do any practical experiments you like in aid of your research." He had to thank those gentlemen. Then there were other professors and scientific experts, members of the Institute, and other persons outside, who, when applied to, had devoted much of their time and brains in order to assist him in his researches. The honour which had been done him was divided with those gentlemen, and although their names were not engraved on the medal, he would ever see them there. It was one of the proudest moments of his life to stand there and claim to be of the fraternity of Bessemer Medallists. He hoped his future record would be better than his past. In looking over his past work, he was convinced of his fearful ignorance. The more he seemed to get to know, the more ignorant he felt he was. The whole metallurgical world seemed full of fogs and clouds, one "saw men as trees walking," and other workers were beginning to learn what little exact knowledge they had of the science of metallurgy, and to see that there were huge areas which needed investigation and the attention of more research workers. What was known now was a mere trifle

compared to what would be known eventually. He hoped he would be able to assist in the future in rolling away some of the fog and ignorance. He thanked the President, as representing the Institute, for having conferred that great honour upon him, an honour which he would never forget.

The PRESIDENT then delivered his inaugural address.

PRESIDENTIAL ADDRESS.

By WILLIAM WHITWELL.

We meet to-day under very memorable and unique conditions, for not only is this our first meeting in the new century, but also the first in the new reign. It is natural, therefore, that our thoughts should be directed to the characteristic features and achievements of the past century and the last reign. How prolific both have been in great deeds, great scientific advances, great progress in a thousand different directions, and great prosperity for the industries which this Institute represents. Many pages of this address might suitably be devoted to a comparison of the years 1801 and 1901, and 1837 and 1901. But what could I say in such a comparison that has not been said already a hundred times, not only by my predecessors in the chair, but by many other authorities who have made themselves more *au courant* with the world's metallurgical conditions than I can claim to be.

The Progress of the Past Century.

If we look back to the past, we are forced to the conclusion that most of the notable advances made in our art and industry belong to the nineteenth century, particularly its latter half. The principal exceptions are, the use of coal as a blast-furnace fuel by Dud Dudley, the invention of the puddling process by Cort, and the manufacture of crucible steel by Huntsman. All the inventions, discoveries, and improvements of preceding centuries did not succeed in getting a yield of more than 40 to 50 tons a week from a blast-furnace, nor a consumption of less than six to seven tons of coal per ton of pig. Hence, in the early years of the nineteenth century, the world's make of pig iron was less than half a million tons, against 40 millions in 1900; and the make of steel in 1800 was less than 50,000 tons, as against 27½ millions in 1900. If I wanted a text from which to preach

to you a discourse suitable to the place and circumstances in which I stand to-day, I think these figures would adequately supply it. For what do they mean and involve? They are symbolical of a century of the most marvellous material progress that has ever been attained, and some of us think of greater progress than could by any possibility happen in the time to come. They mean the rise and development of the railway system, of the iron and steel mercantile marine, of wonderfully complicated and effective fighting machines whereby Britannia rules the waves; of locomotive engines, marine engines, machine tools, agricultural machinery, and other forms and demonstrations of power; of bridges, viaducts, tunnels, and numerous other structures, that could not have been possible under the former order of things; and finally they mean the amelioration of the conditions of labour and of living in every civilised country that I need not attempt to particularise.

I sometimes wonder whether we of this Institute are not at times too prone to magnify the share that we have taken and still continue to take in relation to the material achievements of the latter half of the century. The chief symbols of the century are the locomotive, the steamship, and the dynamo. The minor symbols are legion. Few symbols in either category would have been possible, as we know them to-day, but for the materials made available by the iron and steel industries. And yet these industries had no general technical organisation until the year 1869, when the Iron and Steel Institute was founded, holding its first autumn meeting of an audience, "fit though few," in the dingy and not over-auspicious Oddfellows' Hall, Middlesbrough. Many things have happened since then. We have been honoured by kings and princes, and have been awarded the world's meed of praise for useful and beneficial work. I well remember the meeting that was held at Newcastle-on-Tyne, September 29, 1868. The suggestion that such an Institute should be established was made by the late John Jones of Middlesbrough, at that time Secretary of the North of England Iron Trade, who read a paper on the position of the Iron Trade in relation to Technical Education. In accordance with resolutions then passed by the members of the North of England Iron Trade, a meeting was convened at the Queen's Hotel, Birmingham, on October 8,

1868. Mr. William Menelaus of Dowlais presided, and proposed the following resolutions:—

"1. That in the opinion of this meeting of representatives of the various iron-making districts of Great Britain, it is desirable to take steps for the establishment of an Iron and Steel Institute for the discussion of practical and scientific questions connected with the manufacture of iron and steel.

"2. That it is desirable to base the rules of the proposed institution upon the general principle adopted by the Civil and Mechanical Engineers' and other kindred societies, rigidly excluding all questions connected with wages and trade regulations."

These resolutions having been carried unanimously, a provisional committee was formed to represent the various iron-making districts, selected from the North of England, West Coast, North and South Staffordshire, South Wales and Monmouth, Shropshire, Sheffield, Derbyshire, and Scotland. At a meeting of this committee in the Westminster Palace Hotel, December 17, 1868, over which Mr. Lowthian Bell presided, rules were drawn up, and it was resolved that the Duke of Devonshire should be requested to become the first President of the Institute. On January 5, 1869, the first voting list of candidates for membership was issued. This included 101 names given in by the members of the provisional committee. The first general meeting was held in Westminster Palace Hotel, Mr. Lowthian Bell presiding. The Duke of Devonshire, K.G., was elected President. The Vice-Presidents and Members of the Council were also elected, Mr. David Dale of Darlington being appointed Treasurer, and Mr. John Jones of Middlesbrough, Secretary. Thus was successfully formed the Institute of which you are members. The Duke of Devonshire delivered his inaugural address on June 23, 1869, in the hall of the Society of Arts, and for thirty-two years the Iron and Steel Institute has continued to flourish as one of the institutions of Great Britain, having a membership extending to most countries of Europe, and to America, India, Japan, and Australia. It is impossible to speak too highly of its work, for it has done much to develop and spread exact knowledge in connection with successful and economic manufacture. Its deliberations have been

presided over by many of the giants of our industry, many of whom, we are sorry to say, have passed away; on the other hand, it is with feelings of greatest pleasure that we realise that one of the earliest of our Presidents is still with us. In his admirable Presidential Address, my predecessor in the chair, Sir William Roberts-Austen, gave so excellent and complete a history of our Institute in his tributes to the work of past Presidents, that it is needless for me to give you any further details in that direction. Following in the footsteps of so formidable an array of great workers, I feel most fully the difficult task I have undertaken in accepting the position to which you have elected me, but, with the example of so many able predecessors before me, it shall be my constant endeavour to maintain the character of our Institute, of which I have had the honour of being a member from its commencement.

The Value of Research.

One of the leading features in the work of the Institute in the past lies in the fact that it has been the medium whereby much valuable research work has been placed at the disposal of its members and the whole metallurgical world. Up to the present we have not been able to offer any direct encouragement to workers in this line, but owing to the munificence of Mr. Andrew Carnegie we have now at our disposal a sum of £6500 for the founding of scholarships and medals for research work in the development of iron and steel manufacture. It is to be hoped that such prizes will encourage those who are already working, and induce others to join the same army, with considerable benefit ultimately to our industry. As to the value of research in the solution of metallurgical problems, and the improvement of our methods of manufacture, there can be no question. If we glance through the records of our Institute, we can find many examples that bear this out. Take for instance the basic process. The way to success was undoubtedly pointed out by the teachings of Percy and Grüner, followed up by the research work on dephosphorisation of Snelus, Edward Riley, Jordan of Paris, and Stead. Thomas himself admitted that these investigations had been of the greatest assist-

ance to him. The Saniter desulphurising process, by which thousands of tons of good steel have been made from pig iron quite unfit if used without the desulphuriser, was founded on pure laboratory experiment conducted by Saniter himself. The research of Stead into the effect of arsenic on steel, proving this element not so pernicious as was at one time thought, has opened up the use of ores which were previously condemned on account of their arsenic contents. The investigations on the heat treatment of steel by Brinell, Tschernoff, Osmond, Howe, Sauveur, Roberts-Austen, Stead, Arnold, and Campion have given us the correct temperatures and treatment which steel must undergo to produce the best structure with the best mechanical tests. In the *Iron Age* for December 20, 1900, there was given an account of some radical changes in the arrangements of the Edgar-Thomson Steelworks of the Carnegie Company, carried out by Kennedy and Morrison to introduce a new method of rolling rails founded on the facts brought to light by the researches on heat treatment. The work of Hadfield on the effect of manganese produced that wonderfully useful material known as manganese steel. Many more illustrations of the value of research work in the preparation of new alloys of iron might be given. These examples, however, fully illustrate the value of research, and in the future developments of the manufacture of iron and steel, research will of necessity play an important part.

Problems in Metallurgy awaiting Solution.

In the progress of the past century certain achievements stand out more prominently than others. Two of the most important are, the reduction of waste, and the utilisation of waste by-products in all manufactures. Comparing the beginning with the end of the century, we find a wonderful and enormous change in the economy of the production of a ton of iron or steel. Many things are responsible for this very satisfactory result, among which may be mentioned the application of hot-blast by Neilson, the inventions of Bessemer and Siemens, the great increase in the size of furnaces and the power of our machinery, and last, but by no means least, a better understand-

ing of the various phenomena of iron smelting and subsequent treatment. But though we have advanced so greatly, there are still many problems in our iron and steel industries awaiting solution; problems touching the prevention of waste and the utilisation of waste by-products.

WASTE HEAT IN BLAST-FURNACE WORKING.

There are two items of waste heat in our blast-furnace operations which must be self-evident to all who have watched the tapping of furnaces, namely, the loss of the heat contained in the iron and the slag. Using the heat requirements given by Sir Lowthian Bell in his monumental work on the "Principles of the Manufacture of Iron and Steel," it is very easy to calculate these amounts of waste heat. Taking the iron first, the results are as follows:—

Heat lost in 100 tons of pig equivalent to 4·125 tons of coal. Thus in a blast-furnace plant producing say 100,000 tons yearly, the heat lost in the iron will equal 4125 tons of coal. The total make of the Cleveland district approximates 2¼ millions yearly, and the heat in this weight of iron will be equal to 92,800 tons of coal. If in all our various manufactures it were possible to use the whole of the pig iron made direct from the blast-furnaces in the molten condition, in our foundries, ironworks, and steel-works, the problem of utilising this waste heat would be readily solved. Such a condition of things is not likely to occur for some years to come, and though we do at present use some of this 2¼ million tons direct for the manufacture of steel, the amount so used is not a very large proportion. All the rest is cast into pigs, and the heat lost. The problem to be solved, therefore, is how to cast the iron into pigs and utilise its heat also. The method of casting in sand is still by far the most universal one, and most of the iron so cast is judged by fracture as regards quality. Judgment by fracture only is, however, decreasing in importance; the composition as shown by analysis is considered the best guide. Hence casting in sand might be done away with, and some method of casting adopted which would utilise some of the heat now allowed to go to waste.

The heat in the slag is a more serious item of waste than in

the case of the iron. A furnace working on Cleveland ironstone produces 30 cwt. of slag per ton of pig, or 150 cwt. of slag to 100 tons iron. The heat in 150 tons of slag is equivalent to 10·3 tons of coal. Thus in a blast-furnace plant producing 100,000 tons Cleveland pig yearly, the heat lost in the slag will be equivalent to 10,300 tons of coal. The total make of Cleveland pig approximates 1,300,000 tons, carrying with it 1,950,000 tons of slag. Add to this 720,000 tons of slag produced in the manufacture of other kinds of iron, and we get a total of 2,670,000 tons produced yearly in the Cleveland district. The heat in this weight of slag is equal to 183,340 tons of coal, and if we add to this the loss in the iron, the total amounts to 276,140 tons, over a quarter of a million. At 10s. per ton this is equal to £138,070, representing the value of the waste heat in the iron and slag of the Cleveland district.

It would, of course, be impossible to recover all this waste heat and apply it to some useful purpose, but a large proportion of it should be reclaimed—a problem for metallurgists and engineers to solve.

As far as I know, only Sir Lowthian Bell in this country has attempted to utilise the waste heat in the slag. Some years ago he took out two patents, the first being as follows: The slag ball was run into a bath of water under a saltpan, the steam rising underneath the pan and heating the brine. This was not successful.

In the second patent, the slag balls were run into a brick-lined chamber, the roof of which was a saltpan, and the exhaust steam from the blast-engines was turned into this chamber. When the balls were in the temperature rose to 500° to 600° F., the steam before going in being about 212°. This was sufficient to evaporate the brine, and for some time salt was manufactured in this way. The brine contained 22 per cent. of salt, the pans were 20 feet square, and 44 lbs. to 47 lbs. of salt per square foot of pan was made. This was also abandoned owing to the action of the heat on the bogies, as the chamber acted almost like a soaking-pit, and also if a ball burst inside, it practically meant cooling down the chamber so that men could go in and clear away the destruction. This naturally meant a stoppage of the pan during the cooling down and clearing of the chamber.

There is one direction in which the heat of the slag might be utilised, that is, in the drying of wet ores which are used direct in the blast-furnace. The ores from Bilbao often contain over 10 per cent. of moisture. Taking the percentage of moisture in the mixture used for the furnace charge at 8 per cent., there will be 3·04 cwts. of water in the 38 cwts. of ore required to make a ton of hæmatite pig iron. The evaporation of this water will use heat equivalent to 0·407 cwt. of coke as burnt in the blast-furnace. This means 2·35 tons of coke per 100 tons of pig, or about 18½ tons per furnace per week. If we could dry these ores by the waste heat of the slag not only should we save coke, but the furnace would work much more freely. When the ores are wet and in a sticky condition, a perfect mixing of ore, coke, and limestone in charging is not easily attained, the ore remaining in sticky masses, causing irregular working and liability to hanging. Also the gases are so full of steam that they burn very badly, and where a plant is making nothing but hæmatite pig it is often difficult to keep up full steam pressure without firing the boilers with coal to a small extent.

This question of waste heat is one which touches all departments of iron and steel manufacture; but what I have said above shows very clearly that in blast-furnaces alone there is a mine of wealth in waste heat waiting for some one to successfully tap. This is certain, that the time will come when it will be a problem which will have to be tackled and solved if it is possible to do so.

Utilisation of Waste By-Products.

The principal by-products of the blast-furnace are gas and slag. The former has for many years been successfully applied for heating stoves for the hot blast and raising steam for the blowing engines, pumps, lifts, &c. Seeing that in a well-appointed plant the waste gases are sufficient to supply all the needs of the working of the furnaces, it would seem at first sight that this waste product is being fully utilised. But the problem of using this gas in gas engines, and so producing power direct, has of late years engaged the minds of engineers and metal-

lurgists at home and abroad. Though more experimental work in this direction has been carried on abroad than in this country—notably by the John Cockerill Company of Seraing—it is only fair to mention that one of our vice-presidents, Mr. James Riley, was one of the first to apply in a practical though limited way Thwaite's system of utilising the power in the gases at the Wishaw blast-furnaces of the Glasgow Iron and Steel Company some six years ago. In the last two years we have had two papers on the subject by Mr. A. Greiner, Member of the Council, and the new system appears to have derived a great impetus by the success of the gas engine, which was shown by the Cockerill Company at the Paris Exhibition. In Mr. Greiner's first paper he quoted figures showing a surplus of 2000 horse-power per 100 tons of daily make of pig iron, which, in order not to be over sanguine, he reduced to an estimate of 1000 horse-power per 100 tons of pig. In my firm's plant of three furnaces at Thornaby the figures work out as follows:—

Total gas per hour, 2,628,000 cubic feet. Half of this is used by the hot-blast stoves, and about 239,000 cubic feet by the boilers which supply the gantry lift, leaving 1,075,000 cubic feet for raising steam for the blowing engines, pumps, and furnace hoist. Taking the requirements of a gas engine at 130 cubic feet of gas per horse-power per hour, this 1,075,000 cubic feet of gas is capable of producing 8269 horse-power. The horse-power of the blast engines, pumps, and furnace hoist engine total 1388, leaving a surplus of 6881. Taking an ordinary day's make at 350 tons, this gives 1900 horse-power per 100 tons in favour of gas engines. This calculated result comes out very close to the figures quoted by Mr. Greiner, but if to be on the safe side we take his reduced estimate of 1000 horse-power as the surplus, we get a wonderful result when taken over such a district as Cleveland. The make per day approximates 6100 tons, and at 1000 horse-power per 100 tons we have a surplus of 61,000 horse-power, equal to the consumption of more than half a million tons of coal per year. The uses that this power might be put to are endless, driving all the machinery in the works, and supplying electric light and power for outside consumption. Though this problem of utilising blast-furnace gases is not yet completely solved, I feel

certain it very soon will be, and we may see the day when, as my predecessor somewhat humorously suggested, our blast-furnaces will be power producers, with the pig iron a by-product.

We can now arrive at an estimate of the waste going on in the blast-furnaces of the Cleveland district:—

Horse-power in the gases, 61,000.

Waste heat in the iron and slag, equal to 276,140 tons of coal, or 31,500 horse-power.

Total power going to waste, 92,500 horse-power.

The horse-power of Niagara Falls is estimated at 7,000,000. The amount at present supplied by the Niagara Fall Hydraulic Power and Manufacturing Co. is about 30,000. Our waste, then, may be looked on as a small Niagara, which, if we could see in the form of a waterfall, would very speedily convince us of the enormous amount of energy being lost.

Utilisation of Slag.

The total make of slag in the Cleveland district is 2,670,000 tons yearly. Many attempts in the past have been made to utilise it and turn it to some useful purpose, with more or less success; but the accumulation of slag goes on, and great useless unsightly heaps are extending in all directions. A stranger from the South of England passing by one of these huge slag hills one rather misty day caught a glimpse of it through the smoke and fog, and thinking it one of the famous Cleveland hills, was anxious to know the name of it. It certainly was a Cleveland "hill," but not such as he was thinking of. Many firms at Middlesbrough not having tipping-ground have to send it out to sea at a cost of over a shilling per ton of iron.

The principal uses of slag at present are road metal and paving blocks, or scoria blocks, as they are called. It also forms the basis of artificial stonework and concrete flagging, but these consume only a small portion of the total make, and the problem is to succeed in the directions in which others failed in the past, and also, if possible, find other and more extensive means of utilisation.

The setting properties of granulated slag or slag sand, when

suitably treated, have long been known. In 1887 Mr. J. E. Stead read a paper before the Cleveland Institution of Engineers on "Hydraulic Cement from Cleveland Slag." The process he described consisted in mixing and grinding to an impalpable fine powder 75 per cent. dried slag sand and 25 per cent. slaked dry lime. The powder so produced is slag cement. In strength it compared most favourably with Portland cement, and there seemed every probability of the process being a success, and an important industry established. The main element in the success of the cement rests in the extreme fineness to which it is ground, and this proved the main difficulty, as grinding machinery was speedily destroyed by the slag sand. Since then, however, grinding machinery has been very much improved, and there seems no reason why this manufacture should not be taken up again and made a success. The Skinningrove Iron Co. have given us a very practical example of what can be done with slag cement, for their shipping pier is constructed with this material. The important point about this pier is that the cement was made from ordinary slag, without any desulphurising process being adopted, and contrary to the arguments as to the disintegrating effect of the sulphur, in the form of calcium sulphide turning to sulphate, and the speedy destruction of the pier in consequence, it shows to-day no such signs of decay. On the Continent great progress has been made in the manufacture of slag cement. Some interesting details were given by Mr. C. von Schwarz in his paper read before the Iron and Steel Institute last year.

For some years Messrs. Wilsons, Pease & Co., under the direction of Mr. Charles Wood, manufactured at the Cleveland Slag Works, Middlesbrough, bricks from slag for building purposes. Slag sand mixed with selenitic lime was pressed in bricks in a brick press, stacked under wooden sheds to air-harden for seven days, and then in the open air for five to six weeks to further harden, at the end of that time being ready for the market. The selenitic lime was composed of 80 per cent. unslaked lime, 10 per cent. raw gypsum, and 10 per cent. iron oxide, and 6 cwt. of this mixture was used per 1000 bricks. Buildings constructed of these bricks twenty years ago are in a very good state of preservation at the present time, the bricks

being both hard and tough. Many thousands were shipped to London. Their price was at that time 12s. per thousand, which did not leave much margin for profit, but seeing the present high prices of building materials, there would be a better chance of the manufacture proving remunerative. The appearance of the bricks is somewhat against them, being of a dull grey colour.

Slag sand ground fine in a mortar-mill with 6 per cent. slaked lime produces an excellent mortar. It sets rather quickly, a disadvantage in one way, as mortar left over the week-end is useless on the Monday. Mr. T. Kirk, of the Carlton Iron Company, informs me that for many years he has not used any lime at all for mortar, all for his building operations having been made out of slag. He grinds together a limey slag and a quarter of its weight of old brick rubbish, with a few clinkers. A good pug-mill is required, and it is essential that the grinding be done most thoroughly. Sometimes granulated slag is used. This mortar sets rather slowly, but sets very hard. In a town like Middlesbrough, where building operations are always being extensively carried on, mortar could be supplied at a constant and cheap rate.

Slag wool is still manufactured, and the production of scoria blocks is increasing. The latter are now being shipped from Middlesbrough, and if they were better advertised and the sale pushed, a much greater demand would undoubtedly be created, particularly as their value for paving purposes has been so clearly demonstrated in the towns of the Cleveland district.

Blast-furnace slag which is sufficiently soluble to become decomposed in the soil has some value as a fertiliser, not only for the lime it contains, but also, probably, for its contents of silica.

But in spite of all these more or less successful attempts at the utilisation of slag, we are practically as far off as ever in getting rid of, usefully, this costly and unwieldy waste product. It has been clearly shown that useful materials can be made from it, and the problem before us is to make their manufacture a success commercially, and at the same time find out some other means of utilisation which will use up, if possible, all the slag made.

The Extraction of Cyanide from the Blast-Furnace.

In Bell's "Principles of the Manufacture of Iron and Steel," analyses of the fume at different levels of an 80-feet furnace are given. At a distance of 26½ feet from the tuyeres, the fume contains 89·2 per cent. potassium cyanide. The demand for this substance has of late years increased enormously, owing to its extensive use in the gold-fields. Attempts are now being made to extract it from blast-furnace fume, by inserting tubes about the boshes, drawing off the fume, condensing and collecting the potassium cyanide. Should this prove successful, it will become a valuable by-product.

The Production of Pure Pig equal to best Swedish.

The demand for Swedish pig for high-class steel exceeds the supply. Why not, then, in this country produce, as they are doing at Johnstown in America, pure pig to meet this demand? The method used is Bell's washing process, using hæmatite pig and conducting the operation in a Pernot revolving furnace. By this means a material is made very low in silicon, manganese, sulphur, and phosphorus, and may be used for the same purpose as Swedish.

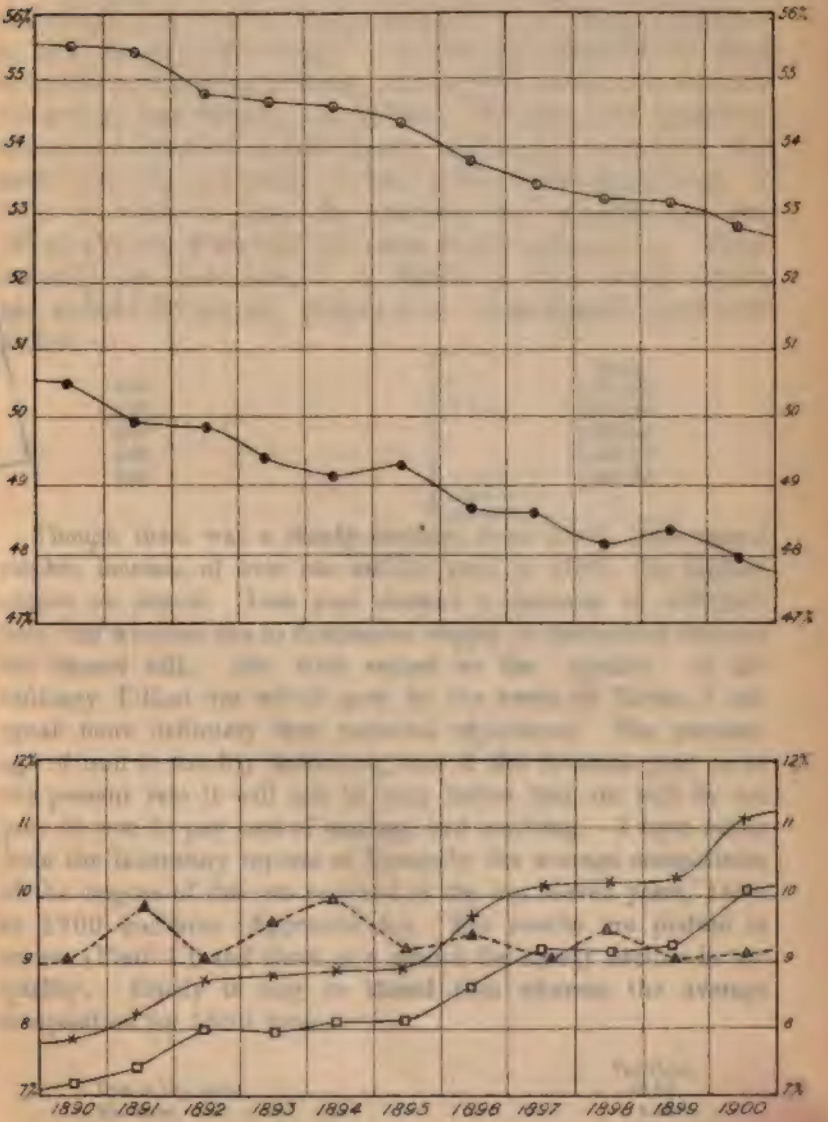
This subject of problems in metallurgy has been but touched upon in the foregoing, and those more intimately acquainted with the needs of steel manufacture than I am, could no doubt point out many more such problems, and none of our young metallurgists need despair of finding something to work at for the future development of our industry.

The Pure Iron Ore Supply.

By far the greater part of our steel in this country is made by the acid Bessemer and Siemens processes, requiring a pure pig iron as low in phosphorus as possible. The question, then, of the supply of pure ore to make this class of pig iron, is one which will have to be faced by us in the near future. Our only

PLATE I.

AVERAGE COMPOSITION OF BILBAO "RUBIO" IRON ORE, RECEIVED AT THORNABY IRONWORKS, 1890 TO 1900.



○ IRON IN DRY ORE. × SILICA IN DRY ORE.

● IRON IN THE ORE AS RECEIVED. □ SILICA IN THE ORE AS RECEIVED.

△ MOISTURE.

Ballantyne, Hanson & ...

native supply of pure ore of the Cumberland district is rapidly approaching exhaustion. In many works the ore now used is of very much lower yield of iron than it used to be, and Spanish and other foreign ore is being imported in increasing quantities to help out the local supply. On the east coast and in other hæmatite iron-making districts, nothing but foreign ore is used, the greater part coming from Bilbao. We often hear reports of the near exhaustion of this famous deposit, and recently it was stated that the end would be seen within a few years' time. I have no means at hand for verifying this estimate, and the Bilbao exports of the last five years do not enlighten us. These statistics are taken from C. E. Muller & Co.'s annual report, and include the ore also shipped from north Spanish ports near Bilbao:—

	Tons.
1896	5,047,000
1897	4,959,803
1898	4,633,241
1899	5,864,174
1900	5,268,429

Though there was a steady decrease from 1896, there was a sudden increase of over one million tons in 1899, the highest export on record. Last year showed a decrease of 600,000 tons, but whether due to diminished supply or diminished demand we cannot tell. But with regard to the "quality" of the ordinary Bilbao ore which goes by the name of Rubio, I can speak more definitely from personal experience. The percentage of iron is steadily decreasing, and if the decrease goes on at the present rate it will not be long before this ore will be too poor in iron to pay cost of carriage and smelting. I have taken from the laboratory reports at Thornaby the average composition of the cargoes of this ore received in the last eleven years, 1890 to 1900 inclusive (Appendix A.). The results are plotted in curves (Plate I.), and show at a glance the steady decline in the quality. Briefly it may be stated that whereas the average composition for 1890 was—

	Per Cent.
Iron in dry state	55·50
Moisture	9·00
Iron in the ore as received	50·50
Silica in the ore as received	7·10

The average for 1900 was—

	Per Cent.
Iron in dry state	52·80
Moisture	9·10
Iron in the ore as received	47·99
Silica in the ore as received	10·09

This decrease of 2·5 per cent. in the iron, and increase of 2·99 per cent. silica in the ore as received, may not at first sight appear very alarming, but if the effect on the weight of raw materials used in a year's working is considered, the seriousness of the difference is more apparent.

To make a ton of pig iron, 1·821 tons of ore of the composition shown for 1890 would be required, but in 1900 it would be 1·917 tons. Our make at Thornaby approximates 125,000 tons of pig iron yearly, made from a mixture of which Bilbao Rubio ore forms half to two-thirds, but in order to more fully illustrate the deterioration of this ore we will suppose nothing but Rubio is used. Then, to produce 125,000 tons of pig there would be required 227,625 tons of ore in 1890, but in 1900 the weight of ore would have to be increased to 239,625 tons to make the same weight of iron, an increase of 12,000 tons. The comparison does not end here, however, for practically the whole of that 12,000 tons is increased earthy matter which would have to be fluxed and passed off as slag. The silica in 1890 is 7·10 per cent., and in 1900 10·09 per cent., giving 16,160 tons and 24,178 tons of silica respectively in the weights of ore quoted above. This is an increase of 8018 tons. The proportion of silica to lime in a hematite slag (when the alumina is 12 to 14 per cent. and the magnesia 4 to 6 per cent.) is 1 to 1·45, so that this 8018 tons of silica would require 11,626 tons of lime, equal to 22,360 tons of limestone. This extra limestone and resulting extra slag would need more coke for the decomposition of the former and fusion of the latter, amounting to over 1 cwt. to the ton of pig, or 7500 tons for the year. Thus the decrease in the yield of the ore for 1900 as compared with 1890, causes an increase of 12,000 tons in the weight of ore, 22,360 tons in the limestone, and 7500 tons in the coke, a total increase of 41,860 tons in the raw materials to produce the same weight of iron. Naturally such a condition of affairs would mean either very much in-

creased rate of working or, what is more likely, a diminished output.

In the light of such a showing as this, one naturally turns to the possibility of there being other deposits near at hand to help off or even become a substitute for Rubio ore. I myself, in the past twelve to fourteen years, have tried several different kinds of ore, from various countries, with this object in view. I attach a full list of these (Appendix B.), giving the composition, mechanical condition, and remarks as to suitability, &c. The value of these analyses lies in the fact that each one represents the composition of a "cargo," and not just a small sample, and in some cases the results are the average of several cargoes. They are thus all of full practical value. The countries represented are Sweden, Norway, South Spain, Italy, Greece, and North Africa. Though many have been very useful as a mixture for Rubio ore, it must be confessed that in no case have I found one which could be considered an efficient substitute. Either the composition, mechanical condition, costs of carriage, or insufficient supply has been the stumbling-block. When it is remembered that the total exports from Bilbao and other ports in North Spain to the north-east coast of this country last year totalled 1,708,167 tons, and from all other parts, South Spain included, only 655,829 tons to the same district, it is evident that unless these other sources are capable of very much increased output, insufficient supply will be the main difficulty in the event of the Bilbao district being worked out. In the last few years magnetic concentration has been brought more prominently forward as a possible means of solving this question of the pure ore supply. The concentration of iron ore by this method has been successfully accomplished in Sweden and in the United States, but before the concentrates can be used in the blast-furnace they must be made into briquettes, as the separated ore is in a dead fine condition, in which state it would be impossible to use it in the furnaces. This must add to the cost considerably, and only under most favourable conditions will it be possible to look for help in magnetic concentration. The improvements in the basic open-hearth steel process that have already taken place, and further improvements in the near future, will soon make this

class of steel cheaper than any other. Thus, in order that the acid process may compete with it, it will be necessary to supply hæmatite pig at cheaper rates. Any one, therefore, who carefully considers what I have shown with regard to the supply of pure ore, must see that the possibilities of a cheaper hæmatite pig are not very hopeful, but rather the other way, and the only conclusion we can come to is, that this country will be compelled at no very distant date to adopt increasingly the basic process, and the use of native ore more extensively.

The Bessemer Process.

At the May meeting last year, in the discussion on the Talbot open-hearth continuous process, Sir Lowthian Bell gave expression to an opinion which somewhat startled the metallurgical world, and caused many of us to regret that we could not have the late Sir Henry Bessemer with us to give his view of the matter. Briefly, Sir Lowthian stated that, from his wide experience as one connected with a large railway company, the irregularity of the ordinary Bessemer steel rail was such, that in his opinion the time was not far distant—if it had not already arrived—when the Bessemer process would have to be abandoned, and the open-hearth steel process substituted to satisfy present-day requirements. When we consider the almost incalculable benefits conferred on mankind in the progress of the last century, in which Bessemer's great invention played so very large a part, none of us can think of the abandonment of the process without regret. But sentimental considerations cannot of course be allowed to rule and guide us in such a matter, and, if it be found that the Bessemer process can no longer satisfy the requirements of the time, it will have to make way for better and more reliable methods of manufacture. In this connection it is interesting to recall a personal incident which took place many years ago. At the council meeting of this Institute on October 11, 1881, I sat beside the late Sir William Siemens. Discussing the merits and respective costs of the Bessemer and Siemens steel processes, Sir William remarked to me: "I may not live to see the day, but you may (you are a young man), when Siemens steel will be made nearly as cheaply, and much more

reliable than Bessemer steel." We shook hands and parted, little thinking that that was the last time he would be with us. It is a touching memory, and one possessing great interest to myself.

At this point a few words on the development of the Bessemer steel industry during the last quarter of a century may be of interest.

In the early seventies the manufacture of steel by the Bessemer process was confined chiefly to South Wales, Sheffield, and Barrow, and the product was used almost entirely for railway material, chiefly for rails and tyres. In those days it was the custom to remelt in separate cupolas each charge of carefully selected hæmatite pig iron, which, when melted, was run into the converter by means of a spout. This method of melting was exceedingly costly, not only on account of the large amount of coke required, but also by reason of the high labour cost, and the slow speed of working. At this time an output of 600 or 700 tons was considered a fair week's work for a pair of converters; the methods then in use for changing and repairing the bottoms of the converters involving a great amount of delay, and it was on this account almost impossible to work at a greater speed. By-and-by improvements were gradually introduced; at works where blast-furnaces formed part of the plant, molten iron was taken direct from the furnaces to the converters. At other works dependent upon cupolas, the cupolas were improved in their construction and charged continuously, so that melting was carried on at a quicker rate, and the adoption of what is known as the Holley bottom, or some modification of it, brought about a very large increase in the productive capacity of the converters. Up to this period the process was acid only. None but the purest hæmatite could be used. Then came the discovery of the Bessemer basic process and its rapid subsequent development. This process rendered available for steel-making purposes not only the ironstones of Cleveland and Lincolnshire and the huge cinder-heaps of the Midlands, but it also enabled our Continental friends to open out and utilise for steel-making purposes their large deposits of very suitable phosphoric ores on a scale which up to that time had never been dreamt of. It is due to the basic process

the Continental steel trade has made such strides in recent years. The production of basic steel on the Continent last year was about 7½ million tons, against about 800,000 tons only in Great Britain.

That the basic process has not been adopted more generally in Great Britain is accounted for by the fact that before its discovery a large acid steel industry had been established; many important plants were engaged upon it, and much capital had been invested, not only upon the works themselves, but also in securing large supplies of the necessary hæmatite ores, both in Cumberland and in Spain. This was not the case on the Continent, where the steel industry up to that period was of comparatively small proportions.

With the advent of the Bessemer basic process there was gradually developed a very large demand for soft steel or ingot iron, a quality of metal softer and more suitable for a variety of purposes than had up to that time been produced in any large quantity by the Bessemer acid process. This demand for soft steels has now grown to very large dimensions, replacing, as it has done to a very large extent, puddled iron; it is now being produced by both the basic and the acid process. In connection with the basic process the utilisation of the slag must not be overlooked. At a very early stage the late Sidney Thomas was so greatly impressed with its value as a fertiliser that he was once heard to say that it would not surprise him if the steel became the by-product. The difficulty in the first instance was how best to apply the slag so that the land could derive the fullest value from its manurial properties. After many experiments it was found that the cheapest and best method was to grind it into an impalpable powder; that when so ground and applied to the land the results compared very favourably with those obtained from superphosphates. That this basic slag or Thomas phosphate is now a very important industry is evident from the fact that during 1899 the production of Europe was estimated at 1,493,000 tons. The figures for 1900 are not yet available, but it is believed that the production for that year will prove to be much greater.

After the introduction of the slag industry, the next development of importance was the adoption of the Darby method ef carburising for hard and medium hard steels. This method offected a considerable improvement in the Bessemer basic pro-

cess, as by it far greater regularity can be obtained in the adding of the carbon, and rephosphorisation, which occasionally took place on the addition of the molten spiegeleisen, has been obviated.

Lastly, the introduction of a large metal mixer between the blast-furnaces and cupolas and the converters has ensured a degree of regularity not only in the supply, but also in the composition of the metal to the converters that was not possible when the molten iron was taken direct.

Notwithstanding all that has been done, chiefly in the direction of securing larger output and greater regularity in the product, the waste in the Bessemer process remains practically the same as it was in the early days. Although the purposes for which Bessemer steel (acid and basic) is now being used have increased enormously—fully one half the make in this country being used for other purposes than railway material—it seems probable that by reason of cheaper methods of producing steel, the Bessemer processes will have in future much more serious competition than has been the case in the past. The recent modifications of the open-hearth process by Bertrand-Thiel and by Talbot, aided as they are certain to be by the labour-saving appliances already in successful operation, seem to indicate that we are now on the verge of effecting still greater economies in our steel-producing methods, and unless some means can be devised of reducing the waste in the Bessemer converters, the Bessemer processes, which have served the world so well in the past, are likely to be superseded.

Open-Hearth Acid and Basic Steel.

For regularity and reliability of product the Siemens acid steel process stands pre-eminent. By far the greater part of the open-hearth steel in this country is made by this process, owing to the facilities for obtaining a cheap and efficient supply of hæmatite pig iron, and so long as such conditions continue to exist it will undoubtedly hold its own. But the basic open-hearth process is advancing with rapid strides, and is seriously challenging the position of the acid process as regards the cheapn[illegible] of its product; and this fact, coupled with what I have al[illegible] said on the question of the pure ore supply, would seem t[illegible]

to the conversion of many of the acid hearths into basic at a very distant date. In the developments of the iron and steel industries in the future the basic Siemens process will no doubt claim most attention. The great desideratum of the process would be its adaptability to any class of pig iron within reasonable limits, so as to avoid making a special pig for it. This ideal state of affairs has not yet been reached, but the improvements that have already taken place have considerably widened its scope, and if the promises held out by the facts given in recent papers before this Institute on the use of fluid metal direct from the blast-furnace, by James Riley, Talbot, and Monell, are fulfilled, we may soon get much nearer the ideal than we are at present, and make good steel in any district from local ores. In Cleveland our goal has always been to make from the local pig iron steel of high quality for structural purposes; and though good steel has been made by the basic Bessemer process from Cleveland pig alone, up to within a few years ago a "special" basic pig has generally been made, costing more than Cleveland pig, from a mixture of the local stone, puddlers' tap cinder, and some manganiferous material, either in the form of ore or spiegel slag. Sir Lowthian Bell, one of the earliest adventurers in the Cleveland iron trade, and now the Nestor of the industry, directed much attention to the development of the application of the local ore, in the hope of obtaining steel from Cleveland pig iron. His experiments and researches, culminating in the invention of his washing process, are all widely known, and were published in two papers before this Institute, and will be found in its *Journal* for 1877. By this washing process, in 7½ minutes he removed 10 per cent. of the carbon, 97 per cent. of the silicon, and 95 per cent. of the phosphorus. By prolonging the washing process a material was made containing under 0·3 per cent. phosphorus, which, when rolled into a bar 3 inches by ¾ inch in thickness, bent close double in the cold. The energetic dephosphorising effect of fluid oxide of iron was thus clearly demonstrated, and in an interesting experiment at the Tudhoe Works of the Weardale Iron Company, in which fluid oxide of iron was added to a partly blown charge of Cleveland pig, the action was so violent that a large quantity of the contents was driven out of the vessel. In a furnace known as Price's, and used for puddling, a

more intense heat was obtained than in the usual form of the furnace employed in producing malleable iron. This proved sufficient to melt steel, and thus a considerable quantity of steel was made from Cleveland pig iron at the Royal Arsenal, Woolwich, not later than 1877. Other questions delayed further trials until late in the eighties, when a small open-hearth furnace was erected at the Clarence Works. This afforded results which led in 1899 to the construction of four furnaces, each having a capacity of 40 tons. In these six different qualities of steel are now produced with the greatest regularity from Cleveland pig iron, using the Saniter desulphurising process. By the use of the desulphuriser it is now possible to make good steel from pig iron containing up to 0·3 per cent. of sulphur, and if need be a pig containing 1 per cent. of this element could be successfully treated, though of course at increased cost. The percentage of silicon that may be present in the pig is up to 1·5 per cent. To obtain this in Cleveland iron, without exceptional working and cost, it is necessary to use forge iron quality, in which the sulphur varies from 0·10 to 0·20 per cent. Whether some cheap and effective plan will be devised in the future to deal with more siliceous pig than this, remains to be seen; it is a problem for our metallurgists to work at, and so further widen the scope of the basic process. By the kindness of Sir Lowthian Bell I attach a full list (Appendix C.) of the six qualities of steel made at the Clarence Steel Works, giving analyses and mechanical tests. It is interesting to note that the prejudices of engineers and Lloyd's surveyors against basic steel are fast giving way, and the latter now accept this steel for shipbuilding purposes as long as it complies with all tests, which it does most satisfactorily. I have often heard it said that steel made from Cleveland pig iron would "never" make plates. Whether they considered there was some peculiar and special evil spirit in Cleveland stone very hard to kill, or what, I do not know; but "never" is a long time, and the above results at the Clarence Works prove that it is not wise to be too emphatic in one's prophecies.

Conclusion.

I should just like to say a few words on the subject of technical education in so far as it concerns our use of it in the works of this country. It is being incessantly dinned into

poor John Bull's ears by the press and from public platforms that he must educate, educate, or be hopelessly left behind by his more energetic rivals. The matter is undoubtedly being taken up more zealously than formerly; but the question is, Are we using that education to the best advantage in our industries, or letting much of it go to waste, and the mental abilities of our staff to rust? In an address to the Cleveland Institution of Engineers, our latest Bessemer medallist, Mr. J. E. Stead, brought forward a suggestion which, I think, is worthy of notice. He is of the opinion that in all our free libraries there should be a technical department containing the standard works on the particular industries followed in the town. Better still, he considers that all our big works should possess such a library of standard works on the manufacture in which they are engaged. Periodicals, reviews home and foreign, and proceedings of technical societies should also find a place there, and the head of each department should read up and review all current literature bearing on his particular branch of the industry, and point out to the head manager anything he may find which he considers would be an improvement on their methods. It is a true saying that he is a wise farmer who occasionally takes a peep over the fence to see what his neighbour is doing. A glance at the abstracts of English and foreign papers relating to iron and steel, published in the volumes of the Institute's *Journal*, will show what a great mass there is of metallurgical information stored up in journals and reviews at home and abroad, which many of our heads of departments and men under them never see, nor have a chance of seeing. They cannot be members of all technical societies, nor subscribe to all the journals; and the result is that many useful papers full of information are lost to thousands to whom they would be of the greatest use. This is a matter which our manufacturers must put right as soon as possible, and so make sure that the technical education given to our workers is not lost, or only indifferently used. That we shall have to fight much harder in the future to retain our proud position is inevitable, and all of us will be required to put forth our very best energies. Therefore let it not be said by posterity that in the battle for commercial supremacy we sent our workers into the fight inefficiently equipped in technical knowledge.

APPENDIX A.

Average Composition of Cargoes of Bilbao "Rubio" Iron Ore received by MESSRS. W. WHITWELL & CO., LTD., *Thornaby Iron Works, Thornaby-on-Tees.* 1890 *to* 1900, *inclusive.*

	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.
Iron in dry state . . .	55·50	55·40	54·80	54·70	54·60	54·40	53·80	53·50	53·20	53·20	52·80
Silica in dry state . . .	7·80	8·30	8·85	8·85	8·95	8·90	9·70	10·10	10·10	10·20	11·10
Iron in the ore as received . .	50·50	49·97	49·87	49·44	49·19	49·39	48·74	48·63	48·15	48·41	47·99
Silica in the ore as received .	7·10	7·49	8·04	7·99	8·09	8·08	8·79	9·18	9·14	9·28	10·08
Moisture in the ore as received .	9·00	9·80	9·00	9·60	9·90	9·20	9·40	9·10	9·50	9·00	9·10

APPENDIX B.

Analyses of Ores from various Countries, used at Thorna in the Manufacture

Name.	Country.	Dry State.						
		Iron.	Manganese.	Silica.	Lime.	Sulphur.	Phosphorus.	
Gellivare	N. Sweden	68·50	Traces	2·50	...	·040	·018	
Norwegian	N. Norway	52·60	...	10·90	5·00	·015	·006	
Almeria, A	S. Spain	49·50	3·60	7·25	2·50	·110	·015	
,, B	,,	50·90	1·20	0·80	4·65	·026	·011	
,, C	,,	52·80	1·30	10·85	...	·116	·025	
Aquilas, A	,,	51·40	1·23	7·20	6·25	·040	·013	·1
,, B	,,	53·20	1·64	1·30	6·32	·050	·009	·1
,, C	,,	48·50	2·01	5·70	5·75	·078	·010	
Morata	,,	50·50	1·98	4·30	6·60	·010	·006	
Mazarron	,,	47·90	1·98	4·40	8·80	·073	·016	
Marbella	,,	61·00		6·80	.	·110	·007	
Lucainena	,,	52·70	3·60	6·50	1·50	·040	·004	
Seville	,,	54·20	·11	16·10	·10	·150	·023	·1
,, Magnetic	,,	60·50	..	10·50	...	·450	·011	
Porman	,,	52·00	·66	5·20	1·00	·230	·025	
Serena	,,	55·00	1·70	7·80	1·40	·040	·009	
Garrucha	,,	53·30	1·58	8·50	1·75	·031	·021	
Elba	Italy	64·50	..	3·75	...	·040	·018	
Taffna	Tunis	58·50	1·40	4·00	2·00	·030	·022	
Brika	,,	50·80	1·41	4·10	9·24	·052	·029	
Mokta	Algeria	59·50	.	5·50	.	·270	·017	
Seriphos	Greece	49·80	1·94	3·30	8·79	·049	·017	·0

Ironworks, 1887 *to* 1900, *as Mixtures for Bilbao Rubio Ore*
Hæmatite Pig Iron.

Ore as Received.								Condition.			Cwts. Ore per Ton of Pig.
Iron.	Manganese.	Silica.	Lime.	Sulphur.	Phosphorus.	Copper.	Moisture.	Lumps.	Rubble.	Small.	
								Per Cent.	Per Cent.	Per Cent.	
68·50	Traces	2·50	...	·040	·018	...	Traces	68	18	14	27·4
52·37	...	10·86	4·98	·015	·005	...	·44	62	25	13	35·8
48·26	3·51	7·06	2·44	·107	·014	...	2·50	40	27	33	37·2
46·83	1·10	6·26	4·28	·025	·010	...	8·00	27	19	54	39·6
51·90	1·29	10·67	...	·114	·025	...	1·70	68	18	14	35·6
50·63	1·21	7·09	6·16	·039	·013	·010	1·50	65	20	15	36·6
50·54	1·56	1·24	6·01	·048	·009	·171	5·00	45	30	25	36·4
46·80	1·94	5·50	5·55	·075	·010	...	3·50	49	31	20	39·2
47·77	1·87	4·07	6·24	·010	·005	...	5·40	45	20	35	38·4
46·46	1·92	4·27	8·54	·071	·015	...	3·00	64	26	10	39·4
61·00	...	6·80	...	·110	·007	...	Traces	65	20	15	30·8
48·90	3·34	6·03	1·39	·037	·004	...	7·20	64	23	13	36·8
53·22	·11	15·81	·10	·150	·023	·079	1·80	69	29	2	35·2
60·08	...	10·43	...	·448	·011	...	·70	75	24	1	31·2
48·62	·61	4·86	·93	·206	·023	...	6·50	66	21	13	38·4
50·65	1·56	7·18	1·29	·037	·008	...	7·90	43	25	32	36·4
49·57	1·47	7·90	1·63	·029	·020	...	7·00	18	32	50	37·2
62·24	...	3·62	...	·038	·017	...	3·50	60	22	18	30·2
54·11	1·30	3·70	1·85	·028	·020	...	7·50	21	32	47	34·2
48·00	1·34	3·87	8·73	·049	·027	...	5·50	38	39	23	38·4
58·61	...	5·42	...	·266	·017	...	1·50	68	20	12	32·0
46·56	1·82	3·08	8·22	·046	·016	·019	6·50	65	20	15	39·4

APPENDIX C.

Six Qualities of Basic Siemens Steel made from Cleveland Pig Iron at Clarence Steel Works, using the Saniter Desulphuriser.

	Quality.	Iron.	Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Tensile.	Elongation, 8 In.
			Per Cent.	Per Cent.				Tons.	Per Cent.
1.	Ordinary	99·205	·240	·010	·058	·037	·450	28·2	25
2.	Wire	99·345	·110	·010	·035	·050	·450	25·0	29
3.	Conductivity electricity . .	99·557	·110	·012	·035	·036	·250	22·6	31·5
4.	Wire rope for traction . .	98·765	·550	·100	·035	·050	·500	90 to 100	4 to 6
5.	Steel rails	98·665	·650	·100	·035	·050	·500	...	...
6.	Special	98·706	·300	·025	·043	·046	·880	50 tons in form of wire.	20

REMARKS.

SWEDEN—*Gellivare.*—This *A* quality increases the yield of iron in the mixture, but its weight limits the amount that may be used in our high furnaces. I found ⅛ work very satisfactorily with Rubio. These deposits have been described in papers published in the Institute *Journal* by Messrs. Jeremiah Head (1894, No. I. p. 47), G. Nordenström (1898, No. II. p. 35), and H. Bauerman (1899, No. I. p. 55).

NORWAY—*Norwegian.*—This was a sample cargo of some extensive deposits in the north. As sent to Thornaby there were large masses of siliceous material which could easily be sorted at the mines, and so concentrate the ore somewhat. Being very free from sulphur and phosphorus, it has every promise of being a valuable deposit. No further steps have been taken to open it out more fully.

SOUTH SPAIN—*Almeria.*—There seem to be several different kinds of ore sent out under this name. The ore marked *A* is rather poor in iron and too high in sulphur for high-class hæmatite pig. The high manganese also limits the amount which may be used on the furnace burden, owing to high manganese in the pig having a very corrosive action on acid steel furnace and converter linings.

B. Yield of iron low. In other respects composition good, containing a useful percentage of lime. The mechanical condition is not good, containing far too much small of a dusty character, which readily blows into the flues.

C. This ore is too high in silica to be any help to siliceous Rubio. It also contains too much sulphur and phosphorus for high-class pig.

Aquilas.—Like the Almeria, there are several different kinds under this name. The ore marked *A* is a good one, containing a useful amount of lime. The mechanical condition was good, and the ore worked very nicely. Unfortunately the supply seemed to be very limited. It was called Red Aquilas.

B. This contains a very small percentage of silica and a large percentage of lime. It thus has a surplus of lime which may be usefully applied when mixed with siliceous ores. The coppe

is high, and this somewhat limits its use, though of late years this element has not been considered quite so detrimental as formerly.

C. Rather low in iron. The manganese limits the amount that may be used.

Morata.—Pure ore, contains an excess of lime over silica. Here again the high manganese limits its use.

Mazarron.—Too low in iron. Same remarks apply as in the case of the Morata ore.

Marbella.—Magnetite. Very dense and hard, and consequently refractory.

Lucainena.—A pure ore, mechanical condition good. Manganese too high for extensive use.

Seville and Seville Magnetic.—These ores are high in sulphur, and the first too high in silica. I am given to understand that these mines are now being worked by a new company, and the ore will be better sorted at the mines, with a consequent reduction in the percentage of silica.

Porman.—I have had but two cargoes of this, very widely different in composition. It is not suitable for high-class hæmatite pig.

Serena.—Good ore, but apt to be small and dusty.

Garrucha.—Mechanical condition bad. The small is fine dust, which readily blows into the flues. The iron ores of the South of Spain have been described by Mr. A. P. Wilson (*Journal of the Iron and Steel Institute*, 1894, No. II. p. 182).

Italy.—The qualities of the Elba ore are so well known, and have been so fully described by Mr. H. K. Scott (*Journal of the Iron and Steel Institute*, No. I. p. 141), that comment is needless.

TUNIS—*Tafna.*—Rich ore, but very small.

Brika.—A good excess of lime in this ore, but the phosphorus is rather high.

ALGERIA—*Mokta.*—A kind of magnetite, rather refractory, and too high in sulphur for best hæmatite pig.

GREECE—*Seriphos.*—Too low in iron. Manganese limits its use, in other respects good.

VOTE OF THANKS.

Mr. ANDREW CARNEGIE, Vice-President, who was very warmly received, said that in his opinion the President had in many places put his finger on the exact spot. The lesson of the address was that they must look at home and develop the material they had. He thoroughly believed that their Cleveland iron was going to make good steel. A young man had been elected as a member of the Institute that morning who had come on the ship with him from Homestead, and who was to introduce the Monell process at one of their works. He was just as certain that the basic process would succeed here with Cleveland ironstone as he was that it would succeed in America. In the latter country they had had just the same troubles as in England. He had listened to men who had told him that this ore and that ore would not make steel, but that did not deter him from buying up every mine that nobody else wanted. They got piles of non-Bessemer for a song, and sold them for millions. If it were not irreverent, he would make a slight adaptation of a text to be found in the New Testament, "Seek ye first the kingdom of heaven and all these things shall be added unto you," and would say, "Seek ye first the things of the United Kingdom and the markets of the world will be yours." He would advise Englishmen to get themselves right at home, and not to worry themselves about things abroad. The way to conquer the foreign market was to have control of their own—that was the first essential. The men who were foremost in the home market would beat all others in conquering markets abroad. With regard to the scholarship, he had in his mind a scholarship for research. If the members could see the list of candidates, they would be surprised at the number and the eminence of the men who were the applicants for this aid to research. He did not consider that the Institute had anything to thank him for, but thought it a privilege, for which he had to thank them, for finding him a field in which money could be judiciously spent. He took especial pleasure in moving the vote of thanks, because the President belonged to a class which had made England great. The

Jessops, the Cammells, the Firths, the Browns, and others were the fathers of the steel and iron development, and the Whitwells belonged to that class. There was no doubt that the Institute had elected the right man to fill the right place. In conclusion, he proposed with much pleasure that the most hearty thanks of the Iron and Steel Institute be presented to the President for his highly instructive address, to which he personally had listened with unusual pleasure.

Sir LOWTHIAN BELL, Bart., Past-President, in seconding the motion, referred to the fact that he had had the privilege of acting the part of godfather to the President, and was very glad to hear from the meeting that that nomination was a correct one, and that they had appreciated the merits and accomplishments of his godson. He also took that opportunity of speaking in terms of high commendation of all that had been done in connection with the Institute by his old friend, Mr. Andrew Carnegie. No man had taken more pains to satisfy himself with regard to what had been done in America than he (Sir Lowthian) had done, and he conceived that that was quite consistent with claiming for the Iron and Steel Institute the credit for what it had effected for this country and for the world at large. He knew quite well from the writings of his friend that he was entirely of that opinion—namely, that the Institute had opened up a new life in all matters connected with the manufacture of iron and steel. They had, as Mr. Carnegie said, dispelled all traces of jealousy, and sought to acquire knowledge wherever it was to be had. In his (Sir Lowthian's) youth some of the large establishments of the country appeared bent on preventing the dissemination of such knowledge as they possessed, forgetting that by communicating knowledge to others they would to a corresponding extent become the recipients of knowledge accumulated by others.

The resolution was carried by acclamation.

The PRESIDENT thanked the proposer and seconder of the vote of thanks very heartily for the way in which they had spoken of

him, and he also thanked all the members very sincerely for having accorded the vote so warmly. He could only say, that so long as he filled his present position the members who had been good enough to place him there should have his very best services.

The following paper was then read:—

DUST IN BLAST-FURNACE GASES.

By ADOLPHE GREINER, Member of Council (Seraing, Belgium).

The present paper is a sequel to the communications I have had the honour of presenting to this Institute on certain former occasions—in particular, the May meetings of 1898 and 1900. Its object is to complete the information which may be found useful to all persons interested in the employment of blast-furnace gas in gas-engines. From another more personal standpoint, it will serve to acquit me from the undeserved reproach of having incorrectly stated that gas-engines on the Cockerill-Delamare plan could utilise raw, impurified blast-furnace gas.

To begin with, I wish to remark that my former communications have never had any other basis than facts—proved in each case, and were not founded on more or less hazardous speculation.

In saying as I did at last year's Spring Meeting, that we had at Seraing a 200 horse-power engine, driving an electric motor since April 1898, without the cylinder having been once cleaned, I simply enunciated a positive fact, and I may add that now, after three years' continuous work, the engine runs day and night without having had to be stopped even once for the purpose of cleaning the cylinder. Experience showed us later on the cause of this result, with which I shall deal presently.

On the other hand, the 600 indicated horse-power gas blowing-engine of a similar type to the one exhibited last year in Paris, did not meet with any difficulty in working, and my last communication of the 9th May 1900 was simply a statement of practical results obtained at our works.

We had hardly started, however, in August 1900 with the first of nine 600 horse-power engines at Differdingen (Luxemburg), than, after three weeks' running, we experienced the fatal results of the excessive quantity of dust contained in the blast-furnace gases at these works. We were thus led to examine the amount of solid matter impregnating the gas, and to our astonishment found at Differdingen from 4 to 5 grammes per cubic metre, while

similar researches made subsequently at Seraing did not reveal the presence of more than from 0·25 to 0·50 grammes in the gases from our own furnaces, or, say, ten times less than at Differdingen.

The cleansing of the gas thus became a necessity, and we shall see further on how an absolutely perfect and extremely simple solution of the problem was discovered.

We were thus led to look more closely into the nature of the gases outside Seraing, and I propose to make known the results ascertained by our chemist in eight or ten establishments where he was allowed to analyse the blast-furnace gases for dust.

The first remark called forth by these results is that the degree of pureness of blast-furnace gases varies greatly with different works, and this is easily to be understood from the different natures of the ores smelted. Generally speaking, the gases are purer in works producing hæmatite pig irons from hard ores in lumps, or mixed with purple ores, when, as is the case at Seraing, the dust from these last (always rather heavy) is deposited in the pipes and chambers nearest the blast-furnaces, and is not carried any very great distance. On the contrary, the gases contain large quantities of fine dust in works which deal with oolitic ores, whose impurities consist mainly of a kind of clay which the heat causes to dry, and which the gaseous current carries to great distances—such being the case at Differdingen, and in general throughout the Luxemburg district.

A second important remark is the following: it is a mistake to suppose that the dust can be efficiently separated by depositing in long passages vertical pipe arrangements or chambers of large capacity. The dust is often reduced to such a state of tenuity that the gas continues to carry it in spite of all checks of the kind referred to, and the clouds of white smoke issuing from the tops of high chimneys prove that the gas after travelling hundreds of yards still contains appreciable masses of light solid matter.

I will now proceed to describe how the cleansing of the gas was accomplished at Differdingen. A choice had to be made between two methods. The first, which may be termed the "static" method, consists in the use of a series of scrubbers or

sheet-iron towers containing coke or sawdust, cooled by a spray of water, which plan, first introduced by Mr. Thwaite, is in use in England, and also under different forms at the Oberhausen blast-furnaces in Germany, at Dudelingen in the Grand Duchy of Luxemburg, and elsewhere. This method is somewhat cumbersome and costly to put down, requiring the use of an aspirating fan or exhauster, but it gives perfect results as regards cleaning, as may be seen from the tests made at Dudelingen and recorded in the accompanying tabular statement.

The second method, which we should qualify as the "dynamic" one, is based upon a reaction due to centrifugal force provoked between the gaseous mixture and a spray of water injected into a suitable apparatus. The liquid and solid particles thrown against the periphery of the apparatus are expelled by an opening in the envelope, while the gases which have been mixed and agitated by the action of rotating blades, escape through the exhaust orifice in a perfectly purified condition. Different analyses made at Hörde on gases treated by M. Theisen's apparatus leave no doubt as to this result, the quantity of dust per cubic metre of gas being sometimes reduced to less than 0·01 gramme.

At Differdingen the principle of "dynamic" cleansing has been very simply carried out by using an ordinary centrifugal fan, 1·50 metre in diameter, running at a speed of 900 revolutions per minute, through which the whole of the gases are passed, being drawn in by the central apertures. Water is supplied by a pipe 26 millimetres in diameter, opening into the axial part of the fan. The gas alone is driven out by the fan discharge, the water, charged with dust, being led off by a pipe 50 millimetres in diameter from the lower part of the fan casing.

The gases which, before being brought into the fan, contained 4 grammes of dust per cubic metre, leave it containing only 0·25 gramme, and are in a proper condition for use in a gas-engine without further treatment.

The quantity of water required is very small, and varies with the degree of cleanliness to be obtained. With 10,000 litres of water per hour, the dust in 10,000 cubic metres of gas can be reduced to 0·30 gramme per cubic metre, and with 15,000 litres to 0·20 gramme, or, say, 1 to 1½ litre of water per cubic metre of gas.

Works.	Nature of Ores.	Quality of Iron Made.	Gas on Leaving Furnace.		First Distance to which the Gases are Led.	Approximate Cross Section in Square Metres.	Dust remaining per Cubic Metre.	Temperature C.	Second Distance to which the Gases are Led.
			Dust per Cubic Metre.	Temperature, Celsius.					
Roechling, Volklingen	Oolitic ores of Luxemburg and Lorraine.	Basic	13·6 gr.	50°	160 m.	5	2·38 gr.	35°	...
Aumetz-la-Paix (Furnace No. 1)	,,	,,	4·5 gr.	105°	15 m.	12½	4 gr.	65°	100 m.
Aumetz-la-Paix (Furnace No. 1)	,,	,,	8·3 gr.	190°	,,	,,	7·90 gr.	160°	100 m. with water sprinkled
Rothe Erde, Esch s/a (Furnace No. 3) . . .	,,	,,	Not analysed	Not analysed	35 m.	4·9	4·6 gr.	135°	140 m.
De Wendel, Hayange . .	,,	,,	6·3 gr.	60°	160 m.	4·9	5·2 gr.	50°	120 m.
De Wendel, Hayange . .	,,	,,	,,	,,	,,	,,	,,	,,	,,
Works of Dudelange . .	,,	,,	5·10 gr.	100°	180 m.	3·2	4·75 gr.	51°	Scrubbers with wood wool, 40 m.
Oberhausen	Swedish hæmatite and minettes	,,	5·30 gr.	120°	Water sprinkled 50 m.	3·2	3 gr.	10–12°	180 m.
Cockerill	Spanish ores and purple ore	Bessemer	3 gr.	160°	20 m.	5	1·26 gr.	135°	50 m.

Works.	Approximate Cross Section in Square Metres.	Dust Remaining per Cubic Metre.	Temperature.	Third Distance to which Gases are Conveyed.	Approximate Cross Section in Square Metres.	Dust Remaining per Cubic Metre.	Temperature.	Final Distance to which Gases are Conveyed.	Approximate Cross Section in Square Metres.	Dust Remaining per Cubic Metre.	Temperature.
Roechling, Völklingen .	...	...	...	...	...	...	...	...	...	...	...
Aumetz-la-Paix (Furnace No. 1)	3	3 gr.	50°	...	...	...	...	...	...	...	...
Aumetz-la-Paix (Furnace No. 3)	3	7·55 gr.	50°	...	...	...	...	...	...	...	...
Rothe Erde, Esch s/a (Furnace No. 3) . . .	4·9	3·3 gr.	102°	...	...	...	...	...	...	...	...
De Wendel, Hayange . .	6	4·4 gr.	55°	...	...	...	...	...	...	...	...
De Wendel, Hayange . .	6	3·7 gr.	50°	...	...	...	...	...	...	...	...
Works of Dudelange .	scrubbers with wood wool, 4·9	1·84 gr.	11°	20 m. (two scrubbers with wood wool)	4·9 (two scrubbers with wood wool)	0·375 gr.	10°	100 m.	3	0·220 gr.	10°
Oberhausen	2·8	0·478 gr.	7·10°	60 m. + gasometer 300 cubic metre capacity	...	0·263 gr.	7–10°	...	...	...	...
Cockerill	10	0·98 gr.	115°	110 m.	4	0·51 gr.	35°	water sprinkled 20 m.	4	0·38 gr.	24°

The apparatus takes up little room, and is by no means costly. For an outlay of 10,000 francs (£400), the gas can be cleaned for six 600 horse-power engines.

Mr. Meier, the general manager of the Differdingen Works, intends to carry out more completely the cleansing operations, by sending the gases leaving a first fan through a second one; experience can alone decide whether this improvement is necessary.

It may be of interest to point out that the "dynamic" method of cleaning possesses the advantage over the ordinary one of supplying the gas at a certain pressure (from 20 to 25 centimetres water-gauge), by which it becomes possible to carry it in sufficient quantity through pipes of comparatively small diameter, and thus reduce the first cost.

In conclusion, facts have shown that the cleansing of blast-furnace gas can be effected by simple and economical means. No reason exists why the principle should not be carried further and the gases cleaned before use in the blast-heating stoves or boiler flues. I venture to call the attention of all blast-furnace owners to the immense economy to be realised by this process, which constitutes a new advance in furnace management—so true is it that progress in one direction always calls forth concomitant results in another.

DISCUSSION.

The PRESIDENT said that if Mr. Greiner had anything to ad to his paper, the members would be very glad to hear it.

Mr. ADOLPHE GREINER, Member of Council, stated that he ha no addition to make, except to say that he would show a bott containing a sample brought from Differdingen of the wat mixed with the dust when it came out of the simple apparat which had been described. After a few minutes they would se how the dust was going down, and the immense quantity of du contained in that small quantity of water. He merely wishe to call attention to the simplicity of the process used.

Mr. JAMES RILEY, Vice-President, said that the paper can as a relief to those who had been interested in the progre of the adaptation of the latest arrangement of the use of th blast-furnace gas in gas-engines. For two years or more the had been burdened with a feeling of incredulity to which was not courteous to give expression, but which had yet gaine upon them very considerably. The previous statements made b Mr. Greiner in that room were emphatic, and could not be con troverted at the time, although they seemed to be contrary what one might expect. They were now told that it was ab solutely necessary to cleanse blast-furnace gases in order to hav them work efficiently in gas-engines. Up to a few months a the assurance was the reverse way, but for some time there ha been rumours that matters were not progressing quite sati factorily with the use of blast-furnace gas in engines Luxemburg. His principal object in rising was to say th they could not but admire and appreciate the frankness whi Mr. Greiner had manifested in taking the very earliest o portunity to state that he had been mistaken, and that now had been proved to be necessary to cleanse the gases which we to be used in gas-engines. His own experience of other kinds gases which were supposed to be absolutely clean made him doubtf from the beginning of the statements which had been made by M Greiner. At all events, those experiences made him doubt that

was possible that they could long continue to work those engines with dirty gases. It became a question now whether the partial cleansing to which Mr. Greiner had committed himself that morning might not also be equally mistaken. His own impression was, that before satisfactory results were obtained in the use of this blast-furnace gas in gas-engines—and he believed they would get those results—the gases must be thoroughly well cleansed. He was doubtful about the process which had been commended that morning to the members by Mr. Greiner.

Mr. W. H. Hewlett wished, in the first place, to give expression to the thanks which the meeting owed to Mr. Greiner for giving them some further information on the subject to which reference had been made at the last meeting there in May. He had felt then that some of them had very much dirtier gases than was possibly the case at Seraing, and the Wigan Coal and Iron Company had been following the matter very closely for a long time past. Their gas was gas produced from the alloys of manganese, and when he told them that he had as much dust as 22 or 23 grains per cubic foot,* it would be seen how very much more necessary it was in their case to have a more complete cleansing apparatus than even that which had been alluded to that morning. He had had the pleasure of going to see Mr. Riley's installation some two or three years ago with their chairman, and it seemed to work satisfactorily. But there they had the opportunity of having the gases first of all cleansed by the distillation process, and from that distillation process, of course, they got a considerable amount of profit. Where coke was used and not coal, that profit was denied to any one putting down distillation plant for the purpose simply of cleansing. It had always seemed to him that it was scarcely likely to pay to put down such enormous distillation plant as would be needed in order simply to cleanse the gases for use in the gas-engines. With regard to the static process, he was afraid they had not very much faith in the possibility of that being put up simply to make it pay; but in the dynamic process which had been mentioned they saw a more active process, and he would like to have had a little more

* Equal to about 50 grammes per cubic metre.

information on one point. The paper did not state the quantity of gas which a fan of a certain size, and running at a certain number of revolutions, was competent to deal with. He would like to know from Mr. Greiner the volume of gas that was dealt with. That seemed to him to be one of the important elements in the consideration of the matter. They felt that that might be one of the points which had been alluded to in the address by the President where economies could be effected. And now was the time, after the period of trade which they had passed through, when they did not have much time to attend to these matters, but were somewhat more profitably employed, now was the time for an improvement in that direction which the President had indicated. They would like to go upon those grounds, and the more information they obtained on the plan of cleansing gases before they were used in gas-engines the better.

Mr. F. W. PAUL said he noticed that in the sample bottle of the water and dust shown them that morning by the author there was entire absence of any condensed tar, so that he inferred that that sample had been collected whilst separating the dust from waste gases of blast-furnaces using coke. As many members were interested in blast-furnaces using coal, he should like to ask the author whether the new method of dust separation described had been tried in connection with tarry gases.

Mr. H. PILKINGTON said that he might mention that in the Sheepbridge Works in Derbyshire they had coal-fed furnaces and they had 100 horse-power gas-engines working for some time. They were under no misapprehension as to the necessity for cleaning the gases. The amount of dust at the point where the gas left the furnaces averaged about twelve grammes per cubic metre. Of course in the gas from coal-fed furnaces their difficulty also was the tar. The cleaning of the gas was on the Thwaite system, and the down-comer of the end furnace was about a hundred yards from the washer box. There were a washer box, cooling pipes, coke scrubber, and sawdust scrubber. At first they had not been accustomed to the latter, and they got the tar and dust right through into the cylinder. After having gained a little experience with the saw-

dust scrubber and washing plants, they were able to work with gases almost absolutely clean, and had been doing so for some time. They found that the dust was arrested by the condensation of the tar. They also found that the cleaning plant put down was fairly adequate for the amount of gas used by the engine, and they got it now perfectly clean. It would be interesting if Mr. Greiner would add to their information, now that they had such an extended experience at Seraing, and would state what was the amount of oil used in lubricating the cylinder of the blowing-engine. He had found that with an absolutely clean gas the consumption of oil was considerable. There was one point in the paper which he would like to refer to, and that was the temperature of the gases given. Were these really the temperatures of the gases when leaving the furnaces? because they seemed to him exceedingly low. The author might state that in his reply.

Sir ALFRED HICKMAN, M.P., Member of Council, said that several speakers had referred to furnaces working with coal instead of coke, but none had mentioned what kind of ore was being used in those furnaces. He understood from the paper that it was a question of the ore rather than of the fuel which produced a greater or lesser quantity of dust. The results of the last speaker's experiments would be very valuable if he would state the kind of ore used.

Mr. PILKINGTON said that it was ore from Northamptonshire.

Sir LOWTHIAN BELL, Bart., Past-President, said that as the name of Mr. Thwaite had been mentioned in the course of the discussion, he might observe that that gentleman had done him the honour of calling upon him at the very inception of the idea that blast-furnace gas could be used for the purpose described, and had invited his co-operation in order to demonstrate the possibility of the operation. He had at once signified his willingness to enter into a series of experiments, but on one condition—namely, that the first step to be taken should be to ascertain the means of freeing the gases from the large amount of solid matter which was brought over by the

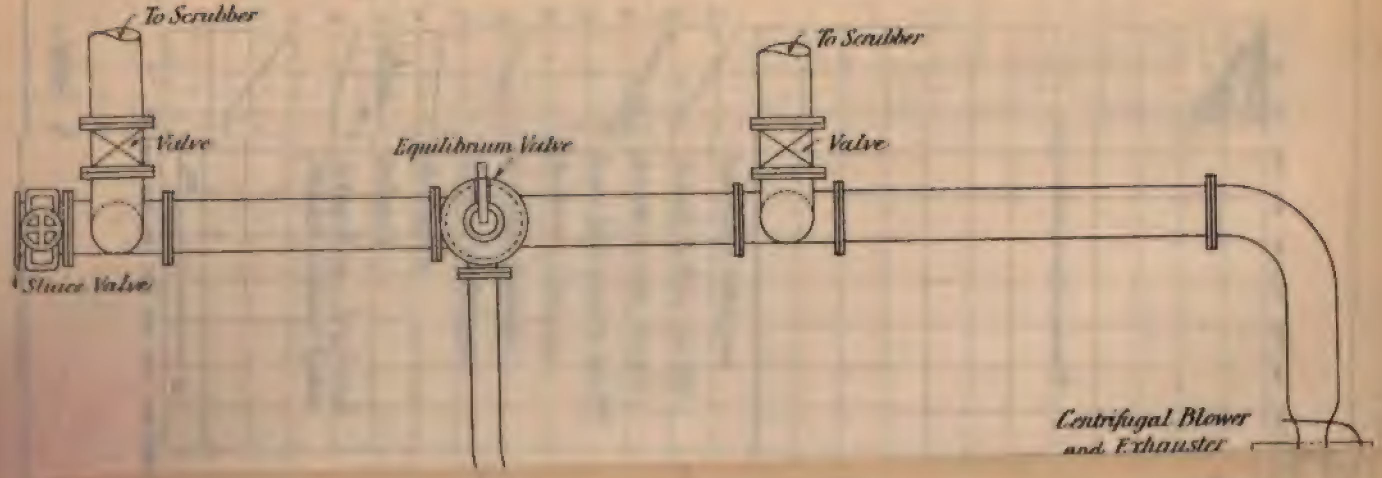
mechanical pressure of the blast itself. Mr. Thwaite, like many inventors, entertained perhaps rather too sanguine an opinion of the efficiency of his proposed plan, and their negotiations in consequence came to an end. It appeared to himself (Sir Lowthian Bell), that by the plan recommended by Mr. Greiner all really gritty matter is entirely removed from the gases as they leave the blast-furnace. On pressure by the fingers the texture is so silky, that it is highly probable that, like finely powdered black-lead, the gases so purified may act as a lubricant in the cylinders.

Mr. G. J. Snelus, Vice-President, said they were all indebted to Mr. Greiner for his very interesting paper. It did appear to him that the dynamic method of separating the dust was of immense importance. At the same time, as Mr. Riley had pointed out, it might be necessary to get the gas even more purified than had at present been done. Mr. Greiner had stated that the manager of the works proposed to use a second fan. He would ask Mr. Greiner whether it was at all possible that if, instead of using water in the second fan, oil were used, then that would have the effect of purifying the first purified gas to a greater extent? Most of the members would know that there was a process of separation of ores now known as the Elmore process, which was done by mixing those ores with oils and separating them. It appeared that heavy oils had a particular effect upon certain bodies; they stuck to some substances and refused to stick to others. It had occurred to him whether it was possible that if oils were used in the second fan it would have a better effect than water. It was a simple thing, and could be easily applied, and would not be costly, because it was quite evident that the oil which was used would be recovered. There would be very little waste in the process.

Mr. Perry F. Nursey said that, so far as he understood the Elmore process, to which Mr. Snelus had referred, the use of oil as a separating agent related only to metallic matter. The oil used in that process, which was a hydro-carbon residue, had a singular affinity for metallic substances, the earthy matter being rejected. It therefore appeared to him that unless the dust of

the blast-furnace gases consisted mainly of metallic particles, the Elmore process would not prove effective.

Mr. Horace Allen said he took a great interest in Mr. Greiner's paper, and asked if he would state the cost of the oil used in the 200 horse-power engine. The journal *Engineering* was responsible for having stated that the cost of oil in running that engine was most serious, and if Mr. Greiner would state the exact cost of the oil, it would be found that that would alone justify the expenditure in capital for an adequate system of cleansing. On the other hand, in order to obtain the best results in the gas-engine, not only should the dust be removed, but the proportion of suspended water should be reduced to that of the atmosphere, and the temperature, if possible, below that of the atmosphere. By that means Mr. Thwaite, in his apparatus, which Mr. Greiner said gave perfect results, obtained, with a gas of 24 per cent. of carbonic oxide and a negligible proportion of hydrogen, a very satisfactory thermo-dynamical efficiency. In his investigations he realised some years back that blast-furnace gas varied greatly in the different works. He also realised, as now admitted by Mr. Greiner, that it was a mistake to suppose that the dust could be efficiently separated by depositing in long passages, in vertical pipe arrangements or in chambers of large capacity; and, as Mr. Greiner rightly stated, the white smoke issuing from the top of the chimney proved that. Mr. Greiner was wrong in stating that Mr. Thwaite's system was somewhat cumbersome and costly to put down. On the contrary, the arrangement was most compact and simple, and the perfect results, admitted by Mr. Greiner, amply justified the capital involved. Without mentioning the saving in cost of lubrication, there was the increased efficiency in the production of power, which amply compensated for the cost of the apparatus, which had such a low depreciation factor as to be considered good and serviceable for half a century, the only care required being a little painting. The amount of water required would, in a carefully controlled plant, be very small. It was impossible to work any rotating apparatus to remove the heavier particles except with excessive cost in renewals and in motive power. With Mr. Thwaite's system, he established pressure, if necessary, up to 50 centimetres of water, so that he could use very much


To Scrubber
Valve
Sluice Valve
Equilibrium Valve
To Scrubber
Valve
Centrifugal Blower
and Exhauster

the first erroneous impressions created by his first paper; it had retarded the progress of the system and done injustice to its pioneer. In the Thwaite-Gardner system it has been the custom, since early in 1899, to employ water in the centrifugal fan, as shown in Plates II. and III., with beneficial results; but, though the high speed of 2000 revolutions per minute was usually maintained, the gas still retained a considerable proportion of light dust, which necessitates the use of tower scrubbers and physical purifiers.

Mr. GREINER, in reply, said it appeared to him that Mr. Riley thought that they could not work without having the gas cleaned. Possibly Mr. Riley had not heard the paper, because it was stated that a 200 horse-power engine was running at Seraing without cleaning the gas; not only at Seraing, but also at Königshof (Bohemia) with a 300 horse-power engine of their type. Another fact was that their 600 horse-power engine at Seraing, with cylinders of a very large diameter, required to have the gas cleaned a little, but not in such a large way as in other works where the gas was very dirty. The fact was stated that in Luxemburg the gas was ten times dirtier than it was in their works. Against that he could say nothing, except that they cleaned it now by a very simple means. He did not say that the Thwaite process was not a good one, but he said the contrary. Mr. Thwaite had been the first to clean the gas in a very able manner, and Mr. Theisen had done so also, but the fan was a very simple thing, and it was also simple to put water in the fan. For that reason he thought there was some merit in the design. They had not done that at all, but it had been done by Mr. Meier himself at the Differdingen works.

In reply to the gentleman who asked if they worked with coal, he had had no experience of gas-engines driven by the gas of blast-furnaces using raw coal; he was familiar only with the gas made by coke in blast furnaces. Necessarily the quantity of oil used for a 600 horse-power engine was not mentioned, because this was outside the scope of the paper; but it might be interesting for members to know that they had a very ordinary kind of oil called Mazout, which was a Russian residual oil.

They used 120 lbs. of that oil per day, and paid 20 centim a litre, which represented 10s. per twelve hours. That was what was required for oiling a 600 horse-power engine.

In answer to Mr. Snelus, he might mention that he had had no experience with regard to oil, but the water used in the fa was recovered. The water was run into a large reservoir, and after standing a few hours the dust was deposited. It was always the same water which was used, and the quantity was 10,000 litres per hour. It had not been stated in the paper that that was the quantity necessary for 10,000 cubic metres of gas, which was equivalent to one litre per cubic metre of gas. One litre of water was a very small quantity, and a cubic metre of gas was a very large one. He recommended the members to read *Stahl und Eisen*, where Mr. Fritz W. Lürmann, the well-known metallurgist, had given a very long paper with regard to the cleansing of the blast-furnace gas. The paper showed how far the Germans were going on with that question at present. He must confess that he was very much astonished that English metallurgists did not understand the question so thoroughly as it ought to be understood.

The President said that he was sure that the members would wish to give Mr. Greiner a most hearty vote of thanks for the paper he had read, and for the share he had taken in the development of that important matter. Having watched the progress in the utilisation of blast-furnace gas as a source of power, he felt increasingly interested in what they had heard that day. He was sure that interest was shared by the members.

The resolution was carried by acclamation.

CORRESPONDENCE.

Mr. William H. Booth sent the following communication:— It was satisfactory to find that Mr. Greiner had now become convinced of the necessity of purifying blast-furnace gas before using it in gas-engines. It was unfortunate, however, that he had

adhered to the contrary belief so long, or that he even promulgated an idea that was so evidently erroneous. From the very beginning of the use of blast-furnace gas in the first engine ever run with it at Wishaw, Mr. Thwaite, to whom the credit was due for the whole system and idea, had consistently advocated purification, and the steady opposition of Mr. Greiner for five years had been harmful, because it led ironmasters to believe that the Thwaite system must be wanting in something or it would be able to deal with unpurified gas, whereas purification always had been necessary—obviously so to any one who had really studied the question. Blast-furnace gas was a magnificent source of power, the waste of which appeared to be criminal, but it was not a powerful or strong gas. Its heat capacity was about 100 British thermal units per cubic foot at atmospheric pressure and temperature. It was not fit to be used dusty as it came from the furnace, nor hot and laden with steam. Cooling was necessary. As regards the principle of dynamic cleansing, this was not new. Fans running at fully the peripheral velocity named had been employed in the Thwaite plant. But a fan, at best, worked badly upon hot gases, and these ought to be cooled to increase their gravity, and made to deposit the heavier dust before entering the fan. It was a mistake mechanically and financially to employ apparatus of too cheap a nature, and to take risks of dust in the engine. To an engineer the mere proposition to employ dust-laden gas in the cylinders of a heat engine savoured of absurdity. It ought not to have been advanced.

It was nothing less than astounding to find British ironmasters so tardy in taking up improvements and economies in this direction. With millions of feet of gas practically wasted, costly power-distributing stations were being erected to generate electricity by steam power produced from fresh coal. That our so-called leaders of industry did not drop some of their old-fashioned ideas and enter into combinations for the use of now wasted gas to produce much wanted power was a proof of the want of energy that has allowed the products of America to oust British products on their own soil. Yet there was not a blast-furnace in Great Britain that was not within reach, by electrical transmission, of some good centre of power production.

Every tramway in the country might be driven by energy generated by blast-furnace gas; and there were furnaces now blown out and standing idle that would pay if set to work as gas-producers, making iron as a by-product. Why was it that in Germany almost every ironworks was alive to the importance of the subject, and in England hardly a breath of interest could be raised, except when Mr. Greiner came over here and first read a paper which stated that the Thwaite system was not necessary, and after five years read another to the contrary, or as soon as Belgium discovered that the English system and invention was the true one.

Mr. J. A. LENCAUCHEZ (Paris) communicated the following: —In October 1899 he was entrusted by the steelworks of Micheville (France) with the preparation of plans for a purification plant of 600 horse-power. This plant was erected early in 1900, and consisted of: (1) An atmospheric condenser composed of vertical pipes through which the gas passed, depositing the coarse dust, and being at the same time reduced in temperature. (2) From this condenser the gas was driven through purifying vessels by an exhaust and blowing fan, running at a speed of 1800 revolutions per minute, and working as an exhauster. Two fans were provided, one being kept as a reserve. Doors were fitted to give easy access to the interior. (3) The purifying vessels were arranged in a manner similar to those in gasworks, but here they worked only as filters. (4) On issuing from the purifying vessels the gas was controlled by a small receiver, under a water pressure of 2¾ inches, before admission to the 300 horse-power Otto engine. The scheme included the installation of scrubbers, but owing to Mr. Greiner's statement at that time (the end of 1899), that no purification was necessary, the construction of these was postponed.

The first trials took place in October 1900, and it was found that, notwithstanding the great resistance of the purifiers, the dust entered the cylinders in such quantities as to stop the engine. The writer was aware that at Dudelingen, in order to keep the fan going, it had been found necessary to introduce water from time to time for cleaning it, but no attention had been paid to this fact, and otherwise there had been

no trouble, as there was a complete purification plant with scrubbers. The idea then naturally suggested itself that the exhaust fan with a large quantity of water would prove a good purifying apparatus. The writer consequently, on the 12th November 1900, informed the manager of Micheville that it was necessary to introduce, on each side of the fan in the centre, a strong jet of water, and that this injection would efficiently purify the gas. It was also recommended to proceed with the construction of the scrubbers. Subsequently, on 10th January 1901, he (the writer) had applied for a French patent for an improved fan with a water spray for purifying gases in general.

In February 1901, after new trials with an exhaust fan, it was decided that this was the best purifying apparatus. The engine has since worked without cleaning, and it will probably be a very long time before this becomes necessary. Similar experiences were made at Differdingen, where they had at first no purification plant at all. Afterwards a Theisen apparatus was put down, and benefiting by the experience gained at the Micheville works, an exhaust fan with water spray was added, which gave the interesting result stated in Mr. Greiner's paper.

These results will probably be of much interest to the members of the Institute, as they are of great importance to the economical application of blast-furnace gas, not only for the direct driving of engines, but to the heating of boilers, and also in the recovery of the by-products of blast-furnace and producer gas, coking plant, &c.

Mr. E. Theisen (Baden-Baden) wished to point out that a fan of ordinary construction was unsuitable for thoroughly cleansing blast-furnace gases, even by spraying water into it and driving the gas over the wetted surface, as was done in the process patented by himself. This was due to the fact that in an ordinary fan the fulfilment of the essential condition for separating the dust was impossible, namely, that of giving to the whirling current of gas a sufficiently long passage over the film of washing water adhering to the inner surface of the casing. By this means alone a really pure gas containing only 0·01 grammes of dust per cubic

metre could be obtained. The gas thus treated was very dry and had a temperature corresponding to that of the cooling water. The cost of construction and working were also lower for the Theisen apparatus than for two or three fans placed in succession in the downtake. These latter required far more power, because in order to carry out one cleansing effect alone, the blades must run at the excessively high velocity of 230 feet per minute, while the Theisen centrifugal, in which the whole operation can be properly carried out, only ran at a speed of 100 feet per minute.

Mr. R. Hanbury Wainford (Newcastle-on-Tyne) communicated some suggestions on dust-catching which occurred to him while working on this subject last year. The so-called American dust-catcher is, according to him, ineffectual. This is an arrangement in which the downcomer is led vertically downwards into a large cylindrical casing, with a hopper-shaped bottom. The open mouth of the downcomer is fixed a short distance above the bottom. The outlet to the flue is placed near the top of the casing. By this means the gases are caused to take a sharp turn upwards on issuing from the downcomer, but the increased area into which they enter very likely sets up a boiling action, preventing rather than inducing the precipitation of dust. He suggests that an improvement would be effected by leading the gases into the casing in a tangential direction, thereby setting up a circular action like a whirlwind. If the specific gravity of the dust is only perceptibly above that of the gases, the centrifugal force would throw the dust against the sides, whence it would fall down into the hopper-shaped bottom. The outlet tube would be carried vertically up inside the casing, having its opening about on a level with the centre of the inlet. A modification of this arrangement consists in fixing a turbine-like disc to the outlet of the downcomer in the casing. The dust is then separated by centrifugal force, and later by precipitation. Another proposal is to have horizontal chambers fitted with baffle plates, so placed as to cause the gases to follow a wavy course in passing through them. The eddying set up behind each baffle plate would cause precipitation of the dust.

Mr. Fritz Lürmann, in the paper * to which Mr. A. Greiner referred in his reply to the discussion, described the progress made in the application of blast-furnace gas as a direct source of power, with special reference to Germany and Luxemburg. The question of the dust, and the various methods which have been tried for effecting its separation from the gases, is very fully dealt with. The author distinguishes between two kinds of dust: the coarse, consisting of coke, iron, and limestone particles; and the finely divided, which does not deposit, but emerges from the chimney, after travelling hundreds of yards, in the form of white smoke. With regard to the former, there never existed a difficulty in getting rid of it; the latter, on the other hand, which varies very much in quantity on different days, is often found to contain alkalies and salts, which attack the lubricant of the engine. At a few works only, however, has the importance of cleansing the gas from this fine dust hitherto been recognised.

With the exception of an installation in Scotland, the most extensive cleansing plants are to be found in Germany, and up to the present Theisen's apparatus has seemed to excel most others in efficiency as well as in simplicity of construction. One of these, which was put to work in Hörde in October last, gave results which were all that could be desired. It remained, however, for the manager of the Differdingen works to discover a still simpler method of accomplishing the purification. This firm, relying at first on their experience that a 60 horse-power Otto-Deutz engine had worked a long time without occasioning the least difficulty, ordered from Seraing nine engines of 600 horse-power each, without taking any steps to get rid of the fine dust. The unfortunate effects of this, however, soon obliged them to put in a Theisen apparatus, which failed in this instance owing to structural defects. The chance discovery at Dudelingen of the beneficial effect of a fan in the downtake, with a jet of water to wash away the accumulating dust, then led the manager to the idea of substituting a large fan with a central jet of water. This arrangement proved so effectual that no further cleansing of the gas was found to be necessary. The author is of opinion that this method overcomes one of the chief difficulties con-

* *Stahl und Eisen*, vol. xxi. pp. 443-459, 489-514.

nected with all cleansing apparatus; that is, the dealing rapidly with a very large volume of gas, since such a fan can with ease pass 1000 cubic metres per minute. The paper contains fifty-one illustrations, among which are a number of engravings, drawn to scale, of the leading types of purifying plant, and complete statistics of many trials are given. The subject was accorded a very ample discussion, and the author expresses his astonishment that both English and American ironmasters have been so tardy in profiting by this source of economy, and indicates in the following table how completely German ironworks have taken the lead in this respect. The table referred to gives the distribution of the total power in the various countries as follows:—

April 18, 1901.	Germany.	Austria.	Belgium.	Italy.	France.	Russia.	England.	Luxemburg.	Spain.
	H.-P.	H.-P.	H.-P.	H.-P.	H.-P.	H.-P.	H.-P.	H.-P.	H.-P.
Seraing . . .	3,900	...	7,600	...	...	700	600	6,000	...
Wetter . . .	2,400	...	...	1,200	...	...	...	...	..
Mülhausen . .	3,000	...	...	...	...	...	...	...	600
Breitfeld, Danek & Co. . .	600	850	...	600	...	...	...	600	...
Schneider & Co. .	...	...	...	...	7,400	...	...	...	...
Total . .	9,900	850	7,600	1,800	7,400	700	600	6,600	600
Körting Brothers .	5,105	...	...	...	...	...	...	...	...
Otto-Deutz . .	10,120	...	...	...	...	30	...	3,200	...
Deutsche Kraftgas Gesellschaft .	12,800	2,000	...	...	...	1,500	...	...	...
Nuremberg . .	6,740	...	...	...	...	...	...	...	...
Total . .	44,665	2,850	7,600	1,800	7,400	2,230	600	9,800	600

Mr. GREINER thought that in reply to Mr. W. Booth's criticisms he could do no better than refer once more to the statement made in the opening sentences of his paper, viz., that that paper and others on the subject of blast-furnace gas, read by him before the Iron and Steel Institute, did no more than give an account of facts, capable of verification at any moment, and were not to be considered as expressions of opinions, whether his own or those of members of his staff.

It seemed idle to mention once more the case of the 200 horse-power engine started at Seraing in April 1898; but repetition, however tedious, could not injure the truth, which was in

this case that an engine had for several years been working with gas simply taken from a pipe at a certain distance from the furnace, much as steam is, under ordinary circumstances, taken from a boiler. The unexpected success of this early experiment led the engineers of the Société Cockerill to accept and generalise the fact, and diverted their attention from a closer study of the causes which tended to produce such an exceptional result. But after all it was mostly by trial and error that modern inventions had been developed and brought into practical shape. The expensive and cumbersome nature of many of the earlier appliances which had been proposed for cleansing and purifying gas, were no doubt a great bar to their employment, and the author felt justified in expressing his conviction that the supposed possibility, mistaken though it may have turned out to be, of being able to dispense with such costly accessories, went a long way in encouraging manufacturers to give a fair trial to the blast-furnace gas-engine.

An important fact, which ought not, moreover, to be lost sight of, was that not only at Seraing had the use of unpurified gas been attended with successful results, but that engines had been running under practically identical conditions at Ruhrort, Westphalia, since March 1901, at the works of Mr. Roechling in Lorraine since April 1900, and at Königshof in Bohemia since February 1901. These engines were all giving perfect satisfaction, as might be ascertained at any time by a visit to the works mentioned.

With regard to the question of "dynamic" cleansing, it was not claimed that the very simple and somewhat makeshift arrangement in use at Differdingen was the best of its kind, or that it would meet all cases. But it had served its purpose satisfactorily, and its success was sufficient to prove that the highly elaborate cleansing plants devised by some inventors might safely be reserved to deal with circumstances even more difficult than those encountered at Differdingen. More perfect appliances might doubtless give better results, but cost was a prime consideration in all manufacturing concerns.

The following were still more recent results obtained at the Differdingen works with two centrifugal fans arranged in succession, and were deserving of consideration :—

Dust per Cubic Metre.

Before the Fans.	After First Fan.	After Second Fan.
Grammes.	Grammes.	Grammes.
3·39	0·78	0·10
3·95	0·61	0·11

The following papers, on "Crystals of Carbo-Silicide of Manganese and Iron," by Mr. J. E. Stead, Member of Council, and on "The Influence of Copper on Steel Rails and Plates," by Mr. J. E. Stead and Mr. John Evans, were then submitted.

CRYSTALS OF CARBO-SILICIDE OF MANGANESE AND IRON

BY J. E. STEAD (MEMBER OF COUNCIL).

THE bears or huge masses of kish, iron, slag, and bricks which accumulate and remain in the hearths of blast-furnaces after they have long been in blast, are interesting objects for scientific research. Many discoveries of definite chemical compounds, and even of real transparent diamonds, have been made in the past; and this note is a description of some clearly defined idiomorphic crystals recently discovered in the hearth of a blast-furnace at Blaina, Monmouthshire.

The furnace for some time previously had been employed in the manufacture of rich ferro-manganese. During the Welsh colliers' strike it was damped down, and eventually was blown out. Mr. E. Poulaine, general manager at the Blaina Works, who kindly supplied me with the crystals, informed me they were found about twelve feet below the hearth, and a foot or two lower than the mass of the "bear" proper. They were found in a cavity of the sandstone foundation of the furnace, into which the liquid metal had entered through some cracks in the stonework, where they eventually crystallised. During its life the furnace made spiegel and ferro-manganese: no silico-spiegel nor ferro-silicon was made.

The photograph (Fig. 1) was taken after the oxide had been removed and is one-third larger than natural size. Fortunately a few of the complete crystals had their terminal faces; they were evenly coated with a layer of what appears to be oxide, tenaciously adherent to the metallic surfaces. On digesting in strong acid, this was dissolved away, leaving the faces dull. Portions of the metallic crystals were separated and analysed, with the following results:—

	Per Cent.	After Deducting 5·16 Oxygen, &c. Per Cent.
Manganese	51·75	54·56
Iron	35·76	37·71
Silicon	3·62	3·82
Carbon	3·71	3·91
Oxygen, &c.	5·16	
	100·00	100·00

On examining the crystals microscopically, it was noticed what to the unaided eye appeared to be homogeneous metal not actually so, as the parts nearest to the surface consiste mixtures of metal and oxide, hence the large balance left accounted for in the analysis of 5·16 per cent.

In endeavouring to ascertain by calculation if the crystals any definite chemical composition, it was found that the rat the atoms of the metals to those of the metalloids is very near

$$(0{\cdot}6\,Mn\ 0{\cdot}4Fe)_7\ (0{\cdot}3Si\ 0{\cdot}7C)_2$$

Professor Bauerman is of the opinion that the crystals

FIG. 1.

a composition sufficiently close to be regarded as the mol expressed by the formula $(FeMn)_3\ (SiC)$.

By calculation it is found that these compounds would the following percentage composition :—

[redacted]

	$(MnFe)_7(SiC)_2$	$(MnFe)_3(SiC)$
	Per Cent.	Per Cent.
Manganese	54·74	54·14
Iron	37·21	36·65
Silicon	4·03	4·60
Carbon	4·03	4·60

At Mr. Spencer's suggestion successful attempts were made to obtain a sufficient quantity for analysis of the unaltered kernels of the crystals. This was effected by treating the whole crystals with strong hydrochloric acid until only the homogeneous central portions remained. After removing the acid and washing with water, the metallic portions were boiled with caustic soda, and were washed in water and alcohol and then dried. After crushing to fine powder, they were analysed with the following results:—

	Per Cent.
Manganese	56·80
Iron	34·80
Carbon	3·90
Silicon	3·31
Not determined	1·19
	100·00

The ratio of the metals to non-metals is $(MnFe)_{15}(CSi)_4$, a result which does not appear to support the view that they were originally $(FeMn)_3(CSi)$.

On examining microscopically the central parts of the crystals where no oxides were present, they were found to be quite homogeneous, and were thus proved to be what are commonly called isomorphous mixtures, mixed crystals or solid solutions. The compound, therefore, may be described as a double salt, and probably consists of a homogeneous mixture of carbo-silicide of iron and carbo-silicide of manganese. The double salt may be called "Carbo-Silicide of Manganese and Iron."

The discovery of these crystals helps one to understand the constitution of ferro-manganese, and possibly also spiegeleisen, and to note that the silicon and carbon do not form separate constituents with the manganese and iron, but unite with the metals, yielding double salts.

Professor H. Bauerman, and Mr. L. J. Spencer of the mineral department, British Museum, have carefully examined the crystals, and each gentleman has described them as belonging to the orthorhombic system.

The following drawing (Fig. 2) is by Professor Bauermaı

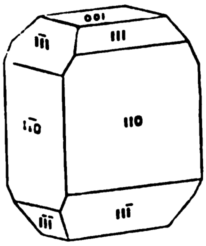


FIG. 2.

Mr. Spencer has made careful measurements of the ε and he has kindly given me permission to introduce his ı which is as follows:—

" *Crystalline system*:—Orthorhombic (holohedral).
Forms:—A prism, *m* (110): a pyramid, *p* (111): the basal pinacoid, *c* (001): the brachy-pinacoid, *b* (010).

"The faces are dull and drusy, and do not give any re: image of the goniometer signal. The mean of several rea taken in the position of maximum illumination gives the f ing approximate values for the angles:—

$$cp\ (001:111)=51^\circ. \quad mm'''\ (110:1\bar{1}0)=66^\circ.$$

"The corresponding axial ratios are:—

$$a:b:c=0{\cdot}65:1:0{\cdot}67.$$

"The drawing (Fig. 3) illustrates the habit of the moı

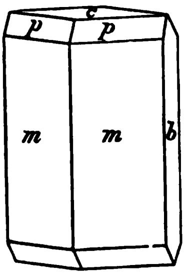


FIG. 3.

tinctly developed crystals with terminal faces. Other cı

show only the faces in the prism zone, and are longer in proportion to their thickness. The largest crystal is about 3 centimetres long, and a crystal of the habit shown in the figure is about 1 centimetre long.

"The whole mass of material consists of an irregular aggregate of these crystals, which are dull iron-black on the exterior. Fractured surfaces show a metallic lustre with a steel-grey colour, usually, however, with a bronze-coloured tarnish. The fracture is conchoidal to uneven, and the material is very brittle. Hardness = 6·5 (Mohs' scale)."

In seeking to trace the genesis of these crystals, the following primary facts are noted :—

1st, That they were not reduced from the ore *in situ*, but that the metallic portions, including some of the carbon and silicon in combination, were derived from the material at a point above the tuyeres, and this eventually percolated through the solid hearth.

2nd, That after reaching the siliceous material in the hearth, the metal suffered very material change.

3rd, That the comparatively large size of the crystals proves that the period during the passage from the liquid to the solid state must have been protracted.

4th, That when the crystals, as found, were fully formed, the still liquid metal, in which they were growing, flowed away, leaving them protruding into a drusy cavity, formerly occupied by the liquid metal.

5th, That eventually oxidising gases, such as steam, carbonic acid, or air penetrated the cavity, causing the superficial oxide coating.

The composition of ferro-manganese varies between—

50 per cent.	and	82 per cent.		manganese.
6	,,	,, 6·7	,,	carbon.
0·2	,,	,, 1·0	,,	silicon.

In no case does it contain so little carbon or so much silicon as was found in the crystals.

It is well known that when manganiferous metals are

melted in contact with siliceous materials, the manganese acts upon and reduces a portion of the silica, according to the following equation—

$$2\,Mn+SiO_2=2\,MnO+Si.$$

In order to obtain in the laboratory conditions similar to those in the hearth of the blast-furnace, where the molten metal was in contact with siliceous matter, a sample of 80 per cent ferro-manganese was maintained at a white heat for various periods in presence of ganister sand. In conducting the experiments, crucibles were lined with the ganister; about 50 grammes of the ferro-manganese were placed on the bottom of each, and this was covered over with a thick layer of ganister. Three experiments were made, in which the crucibles were maintained at whiteness for two, three, and four hours respectively. The following are the results obtained, viz. :—

	Original Ferro-Manganese.	Heated to Whiteness.		
		Two Hours.	Three Hours.	Four Hours.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Manganese	81·27	78·16	75·60	74·00
Iron	11·00	12·45	13·00	13·85
Carbon	6·51	5·73	4·97	3·71
Silicon	0·39	3·33	6·01	7·90
Phosphorus	0·25	0·33	0·36	0·40
Not determined	0·58	...	0·06	0·14
	100·00	100·00	100·00	100·00

Taking the iron as a constant element which did not suffer change during the heating process, it was found by calculation that of 100 parts of the original ferro-manganese used, in each experiment there would remain metal of the following composition and weight :—

	Period of Heating to Whiteness.		
	Two Hours.	Three Hours.	Four Hours.
	Per Cent.	Per Cent.	Per Cent.
Manganese	69·06	63·97	58 70
Iron	11·00	11·00	11·00
Carbon	5·06	4·21	2·91
Silicon	2·94	5·09	6·28
Phosphorus	0·25	0·25	0·25
Loss of manganese	13·21	17·30	22 57
Loss of carbon	1·45	2·30	3·50
	14·66	19·60	26·07
Gain in silicon	2·53	4·70	5·89
Nett loss	12·13	14 90	20·18

According to the equation $2Mn + SiO_2 = 2MnO + Si$, 28 parts of silicon in the silica are equal to 110 parts manganese.

The silicon reduced from the ganister in the above cases is equivalent to:—

	Two Hours.	Three Hours.	Four Hours.
	Per Cent.	Per Cent.	Per Cent.
Manganese = silicon	9·92	18·42	23·09
Manganese actually oxidised	13·21	17·30	22·57

The great discrepancy between the calculated and the actual results in the two-hours' experiment is possibly due to oxidisation caused by the passage of oxidising gases through the crucible lining. The less proportion than that found by calculation in the three and four hours' experiments is probably due to influence of the carbon, which at high temperatures would reduce some of the manganese at first oxidised by the silica. In each experiment, the buttons were thickly covered with graphite, but the solid metals below the surface were quite free from that form of carbon.

These experiments clearly show how it is that the silicon got into the crystals, and they also explain why all "bears" from the hearths of furnaces making manganiferous alloys contain

metal invariably high in silicon, which is as invariably accompanied by large quantities of graphite; for the metal, percolating between the joints of the siliceous bricks, acts upon the silica and the silicon enters the high carburised metal, partially decomposing the carbides and throwing out a portion of the carbon which escapes as graphite.

In the experimental trials, the ratio of the atoms of the non-metals to those of the metals is much greater than in the crystals found in the hearth. Success has not followed the attempt to produce the crystals synthetically, so as to obtain perfectly homogeneous solid solutions. All the metals experimentally produced contained two or more constituents; but all, judging by the relatively greater proportion of one constituent over the others, must have contained double carbo-silicides of manganese and iron.

In the four-hours' experiment, if the carbide of manganese had been quite separate, there would only have been about 65 per cent. of Mn_3C, whereas one of the constituents occupied a volume approximating to 90 per cent. of the whole mass.

It is difficult to explain how the tenaciously adherent oxide was formed on the surface of the crystals. On crushing them to powder, a few centigrammes of the scale were detached and an approximate analysis made of it. The oxide was capable of being attracted by a magnet, whereas the metal from which it was derived was non-magnetisable. An approximate analysis yielded the following results:—

	Per Cent.
Iron	23·50
Manganese	45·80
Silica	10·61
Carbon	3·34
Oxygen, &c.	16·75
	100·00

By calculating all the iron into equivalent magnetic oxide of iron, and the manganese into manganous oxide, the sum total, including the carbon and silica, exceeded 100 parts, proving either that the black scale contained lower oxides than those mentioned, or else some unoxidised metal. A microscopic examination at once showed the latter hypothesis to be the

correct one, and also how it is that the oxide adhered so tenaciously to the metal. During oxidisation the action was evidently not confined to the metallic surfaces, but penetrated for some distance into the mass of metal. The oxide itself contained minute metallic particles distributed through it. The two substances were thus dovetailed into each other, and there was accordingly a complete absence of any clearly dividing line between them.

An analogous condition results on heating certain nickel-steel alloys, when the scale formed adheres with great tenacity to the metal. The iron is oxidised in advance of the nickel, and the scale formed contains free nickel, which is continuous with the unoxidised metal, and binds the two together, thus preventing their ready separation.

On calculating the composition of the scale back into its elements, it is found that both the silicon and the manganese are in excess of what they were in the metal before being oxidised, which tends to show that the oxygen has oxidised a greater proportion of these elements in preference to the iron. The following analyses show this :—

	Scale.		Original Metal.
	100 Scale.	100 Metal, Calculated from Scale.	
	Per Cent.	Per Cent.	Per Cent.
Manganese	45·80	59·00	54·56
Iron	23·50	30·30	37·71
Silicon	4·95	6·40	3·82
Carbon	3·34	4·30	3·71
	77·59	100·00	100·00

It is difficult to account for the excess of carbon over the 3·71 per cent. originally present. Possibly it may have been precipitated from the carbonic oxide, which certainly must have existed in the hearth of the furnace, according to the following equation :—

$$Si + 2CO = SiO_2 + 2C.$$

The carbon was left as an amorphous black powder on dis-

solving out the soluble matter with acid. Graphite was totally absent. Whatever the oxidising agent consisted of, apparently it was too feeble to oxidise the carbon.

In conclusion, I have to express my thanks to Mr. Poulain, Professor H. Bauerman, and Mr. L. J. Spencer, without whose aid it would have been impossible to prepare this note.

THE INFLUENCE OF COPPER ON STEEL RAILS AND PLATES.

By J. E. STEAD (Member of Council) and JOHN EVANS.

The effect of copper in iron and steel is not well known, although much has been written on the subject. It is, however, generally believed, in this country at least, that it has a very deleterious effect. So strong is this prejudice that engineers and others frequently, when buying steel or the material from which it is manufactured, specify that copper must be practically absent. As the facts scarcely justified such practice, it appeared to us desirable to draw the attention of the Iron and Steel Institute to the subject.

Historical.

One of us * has recently given a brief summary of the evidence contained in text-books and elsewhere as to the effect of copper in iron and steel; it is therefore not proposed in this note to refer to any but the most important results of previous work in which analyses and mechanical properties are correlated.

Dr. Edwin J. Ball and Mr. Arthur Wingham † studied the influence of copper on the tensile strength of cast steel. The alloys were made in crucibles, and when melted were allowed to cool in them. Test-pieces 1 inch by $\frac{1}{4}$ inch by $\frac{3}{16}$ inch were cut from the solid metal, and after annealing they were submitted to tensile tests. The results of these are given in the following table:—

* "Copper in Iron and Steel," by J. E. Stead, *Journal of the West of Scotland Iron and Steel Institute*, 1901, pp. 4-16.

† *Journal of the Iron and Steel Institute*, 1889, No. I. p. 123.

Test-Piece No.	Copper.	Carbon.	Tensile Strength.
	Per Cent.	Per Cent.	Tons per Square Inch.
Original Steel	...	0·133	29·0
1	0·847	0·102	18·3
2	2·124	0·217	36·6
3	3·630	0·380	47·6
4	7·171	0·712	56·0
5	4·10	0·183	43·2
6	4·44	trace	34·3

In addition to these tests, forging tests were made. No. 4 forged well in the cold, but was redshort. In concluding their paper, Dr. Ball and Mr. Wingham state that within certain limits copper does not prejudicially affect the mechanical properties of steel, but point out that the experiments were of necessity conducted on a small scale. They presented the results with some diffidence.

Mr. H. H. Campbell * has proved by a large number of experiments that 0·25 per cent. copper has no effect upon the mechanical properties of the steel, excepting that of slightly raising its elastic limit. If anything, the copper steels show greater ductility than steels with less copper. He presents the following table:—

Comparative Physical Properties of Low-Copper and High-Copper Steel Angles.

Thickness in Inches.	Copper.	Number of Heats.	Ultimate Strength.	Elastic Limit.	Elongation in 8 Inches.	Reduction of Area.	Elastic Ratio.
	Per Cent.		Lbs. per Sq. In.	Lbs. per Sq. In.	Per Cent.	Per Cent.	Per Cent.
$\frac{5}{16}$	0·10	11	61,376	44,152	27·52	56·30	71·9
	0·35	17	60,283	43,841	27·88	59·01	72·7
$\frac{3}{8}$	0·10	10	58,965	42,218	28·85	55·50	71·6
	0·35	11	59,630	43,478	29·02	57·86	72·9

Campbell in commenting on these results says: "It will be noted that no difference is to be found in the ultimate strength between steels with high- and low-copper, although all the heats were made in the same way as nearly as possible, the workmen

* "On the Manufacture and Properties of Structural Steel," p. 276, New York.

not knowing either in the Bessemer department or in the rolling mill what kind of iron was in use. Moreover, the high-copper gives a slightly higher elastic ratio, which is a benefit, and also a better elongation and reduction of area."

Professor J. O. Arnold * appears to have had no difficulty in hammering an ingot with 0·1 per cent. carbon and 1·8 per cent. copper. The following mechanical tests made by him of pure iron and iron alloyed with 1·29 per cent. manganese are here given for comparison with the steel alloyed with 1·8 per cent. copper, viz.:—

	Pure Iron.	Manganese, 1·29 per Cent.	Copper Steel.
	Per Cent.	Per Cent.	Per Cent.
Elastic limit	14·39	22·72	30·8
Tensile strength	21·77	32·16	34·8
Elongation	47·00	35·00	30·5
Reduction of area	76·50	65·00	62·2
Carbon	0·04	0·10	0·10
Manganese	...	1·29	...
Copper	...	...	1·81

These results lead to the conclusion that the effect on the mechanical properties of manganese and copper, within certain limits, are comparable. Had the manganese been 1·8 per cent. instead of 1·29 per cent., probably the mechanical properties would have most closely agreed as regards the tenacity, elongation, and reduction of area. The great difference between the effect of manganese and copper appears to be that copper has greater influence than manganese in raising the elastic limit.

Mr. T. W. Hogg † found that copper does not tend to segregate in steel. In the centre of a large ingot, where the phosphorus and carbon had greatly segregated, the copper existed in practically the same amount as it did near the outside. The analytical results were as follows:—

	Inside of Ingot.	Near the Outside of the Ingot.
	Per Cent.	Per Cent.
Carbon	0·75	0·20
Sulphur	0·15	0·036
Phosphorus	0·20	0·042
Copper	0·054	0·052

* *Journal of the Iron and Steel Institute*, 1894, No. I. p. 107.

† *Journal of the Society of Chemical Industry*, vol. xii. p. 236; *Journal of the Iron and Steel Institute*, 1893, No. I. p. 388.

Mr. Albert Ladd Colby,* South Bethlehem, Pennsylvania, i
most exhaustive investigation on the effect of copper in s
shafts, gun tubes, on ship and boiler plates, Bessemer steel r
&c., has proved that steel may contain considerable quantitie
copper without disadvantage. He did not find that 0·56 per c
copper made steel redshort, and the mechanical properties, wh
cold, were quite satisfactory. The following analyses a
mechanical tests of such steel are selected as examples:—

Gun Steel.

	Per Cent.
Copper	0·553
Carbon	0·390
Manganese	0·700
Silicon	0·182
Phosphorus	0·057
Sulphur	0·055

Number of Specimens Tested.	Tensile Strength.	Elastic Limit.	Elongation in 2 Inches.	Contractio Area.
	Tons per Square Inch.	Tons per Square Inch.	Per Cent.	Per Cen
Average.	29·25	17·16	31·12	51·92

Crank-Shaft Steel.

	Per Cent.
Copper	0·565
Carbon	0·250
Manganese	0·640
Silicon	0·149
Phosphorus	0.047
Sulphur	0·034

Number of Specimens Tested.	Tensile Strength.	Elastic Limit.	Elongation in 2 Inches.	Contractio Area.
	Tons per Square Inch.	Tons per Square Inch.	Per Cent.	Per Cen
Average.	35·11	20·64	24·92	44·67

The welding and flanging properties of open-hearth steel c
taining 0·575 per cent. copper and 0·138 per cent. carbon w
most satisfactory, and Mr. Colby naturally points out the ne
lessness of limiting the copper in boiler-fire boxes and structu
steel to 0·050 per cent. or 0·100 per cent.

Mr. W. Lipin † practically confirmed Mr. Colby's work,

* *Iron Age*, November 30, 1899, p. 1; *Journal of the Iron and Steel Institute*, 1
No. I. p. 412.

† *Stahl und Eisen*, vol. xx. p. 536-541, 583-590; *Journal of the Iron and*
Institute, 1900, No. II. p. 551.

extended his researches much beyond the limits of 0·60 per cent. copper. This author found that iron containing up to 3 per cent. copper could be readily worked. Redshortness became evident when it reached 4·7 per cent., and when from 7 to 10 per cent. was present it cracked badly and fell to pieces under the hammer. The following analyses and mechanical tests are given :—

	Original Iron.	Cupreous Steel.
Carbon	0·10 per cent.	0·13 per cent.
Manganese	0·14 „	0·30 „
Silicon	0·09 „	0·14 „
Sulphur	0·034 „	0·009 „
Phosphorus	0·023 „	0·023 „
Copper	Nil.	3·200 „
Tensile strength	26 tons.	46·5 tons per sq. in.
Elastic limit	...	38·17 „
Elongation	27·8 per cent.	13·3 per cent.

It is shown that as the carbon is increased the copper must be reduced, and that if the carbon is 0·43 per cent. the copper must not exceed 2 per cent. If it exceeds that limit, redshortness becomes evident. The same author has shown that as much as 1 per cent. copper may be present in tool steel, but as the hardening effect of copper is so energetic, the quenching of the heated steel must be done in oil rather than in water. It is also stated that copper did not have any deleterious effect on weld iron or in the puddling process.

The evidence given in the careful researches above referred to is most exhaustive and convincing. When it is also remembered that steel rails with above 0·3 per cent. copper have been used in America for many years without any disadvantage, and that Mr. Henri Schneider of the Le Creusot works actually patented a process of adding copper to steel, and claimed that steels alloyed with copper are useful in the manufacture of armour plates, gun barrels, projectiles, &c., it appeared to be scarcely necessary to make further research.

Mr. A. Ruhfus,* however, in discussing Mr. Lipin's investigations, disputes the conclusion that redshortness is not brought about till the copper exceeds 2 or 3 per cent., but admits that

* *Stahl und Eisen*, vol. xx. p. 691; *Journal of the Iron and Steel Institute*, 1900, No. II. p. 554.

0·4 per cent. copper may be present in ingot iron without making it redshort, and that in steel for welding it should not exceed 0·3 per cent. He endeavoured to explain the difference between his results and those of Mr. Lipin by showing that the latter made his experimental steel charges in crucibles which were not so liable to be affected by oxidation, as his own made on a larger scale.

The results obtained by Mr. Colby appear to be a sufficient answer to Mr. Ruhfus' contention; at least for steel made on a large scale with about 0·6 per cent. copper. As, however, Mr. Colby had not experimented with more than the amount referred to, it appeared desirable that further practical trials should be made with steels containing between 0·5 and 2 per cent. copper to ascertain at what point copper does become harmful. We have therefore made several charges of cupreous steel and tested them mechanically.

Report on Experiments made at Eston.

The experiments were made at the works of Messrs. Bolckow, Vaughan, & Co., Ltd., Middlesbrough, and every facility was given us by Mr. David Evans, the general manager, to obtain practical results. To him and to his agents our thanks are due for valuable co-operation and assistance.

The system adopted was the same as that previously used by one of us in determining the effect of arsenic on steel. In each trial the fluid charge of the liquid steel in the ladle was divided into two parts, to one of which was added the element, the effect of which it was sought to determine. Both parts were then cast into the same size ingots. By this means strictly comparable results were obtained, the two parts differing only in the element added. The rolling was carefully watched, the steels were marked, and when cold were carefully tested. Four series of Bessemer rail steels were made containing respectively about 0·5, 0·9, 1·3, and 2 per cent. copper. One open-hearth charge was also experimented upon, to which 0·5 per cent. copper was added. In all cases the cold copper ingots when thrown into the liquid steel readily melted and mixed most perfectly with it. In no case did it deaden or make the steel more lively in the moulds.

In every parallel case the steels containing copper rolled as perfectly as those without it, with the exception of the rail steel containing about 2 per cent. copper, which was torn on the flanges. An examination of the finished rails (2 per cent. copper) showed that this defect was caused by over-heating; the heads, however, were perfect, and after being slotted off were reheated and rolled into wire rod without cracking or breaking up in the least degree. The forgemen and rollers were of the opinion that the steel could be easily worked, and was good, sound material. The companion ingots without the copper under the same heat treatment were not over-heated. We conclude from this that steel with very large percentages of copper, although not redshort in the ordinary sense, will not bear the same amount of heat as when copper is absent, and that its effect in this respect resembles that of carbon and not that of sulphur.

A remarkable result was obtained in the trial with open-hearth steel in which 0·5 per cent. copper was added. In rolling the non-cupreous part every ingot cracked perceptibly, whereas the same steel containing the copper rolled without a flaw. It is difficult to believe that copper will prevent redshortness, but this result would certainly lead to the belief that it does so.

Chemical Analyses of Bessemer Rails.

	Carbon.	Manganese.	Silicon.	Sulphur.	Phosphorus.	Copper.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Series I.—						
Cupreous .	0·42	0·93	0·065	0·030	0·067	0·480
Normal .	0·43	0·94	0·065	0·030	0·063	0·025
Series II.—						
Cupreous .	0·49	0·933	0·075	0·047	0·082	0·889
Normal .	0·480	0·933	0·070	0·047	0·084	0·033
Series III.—						
Cupreous .	0·320	0·640	0·028	0·055	0·048	1·286
Normal .	0·330	1·090	0·028	0·118	0·049	0·012
Series IV.—						
Cupreous .	0·290	0·676	0·084	0·044	0·082	2·000
Normal .	0·310	0·676	0·084	0·047	0·084	0·012

The analyses were made on drillings taken from the rails after they had been tested mechanically.

In Series No. 3 it will be observed that the manganese in

the normal sample is much higher than that in the cupre steel; the sulphur and phosphorus are also different, from wi we must conclude that an ingot from another charge was n by mistake, and therefore the comparison cannot be exact.

Behaviour of Steels during Rolling.

Series I. (Cu. 0·48)	Both steels rolled equally well.
„ II. (Cu. 0·889)	„ „
„ III. (Cu. 1·286)	„ „
„ IV. (Cu. 2·000)	The cupreous rail burst in the flanges during r but it was proved that the material had over-heated. The heads were not flawed. sawing them off they were reheated and rol wire rod without a flaw.

Percussive Tests.

The rails in Series I., II., and III. were of bull-head sec and weighed 90 lbs. per yard. Those in No. 4 series flanged rails, and weighed 56 lbs. per yard.

In applying the percussive tests, pieces of the rails 5 fee length were placed on bearings 3 feet 6 inches apart; a we of one ton was allowed to fall on the heads from a heigh 20 feet in the cases of Series I. to III., and 15 feet in Series After the first blow the weight was allowed to fall a second from the same height. The deflection produced was not after each blow :—

		Deflections in Inches.	
		First Blow.	Second Blow.
Series I.	Cupreous	$3\frac{1}{4}$	$5\frac{11}{16}$
		$3\frac{1}{16}$	$5\frac{1}{4}$
	Normal	$3\frac{4}{32}$	$5\frac{15}{32}$
		$3\frac{1}{16}$	$5\frac{1}{4}$
Series II.	Cupreous	$3\frac{1}{4}$	$5\frac{1}{4}$
		$3\frac{1}{4}$	$6\frac{1}{16}$
	Normal	$3\frac{3}{8}$	$6\frac{1}{4}$
		$3\frac{1}{4}$	$6\frac{1}{4}$
Series III.	Cupreous	$3\frac{1}{16}$	$5\frac{11}{16}$
		$3\frac{1}{16}$	$5\frac{1}{4}$
	Normal	$3\frac{1}{16}$	$5\frac{3}{8}$
		$3\frac{1}{4}$	6
Series IV.	Cupreous	$4\frac{7}{16}$	Broke
		$4\frac{7}{16}$	Broke
	Normal	$5\frac{1}{4}$	$12\frac{1}{4}$
		$6\frac{1}{16}$	$12\frac{3}{4}$

The cupreous rails in No. 4 series had flaws in the flanges caused by over-heating, and in consequence a second blow broke , fracture starting from the flaws. Had the rails been sound, in all probability they would not have broken. All the other cupreous rails stood the very severe test without breaking.

TENSILE TESTS.

Portions of the rails were cut up, and test-pieces were turned into shape for testing by tension. The following results were obtained :—

Series No. I.—Copper, 0·60 per Cent.

	Cupreous.			Normal.		
	Large Head.	Small Head.	Web.	Large Head.	Small Head.	Web.
Breaking weight (tons per square inch)	45·9	46·05	48·3	43·9	44·85	45·15
Elastic limit	25·0	...	...	25·2	...	...
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Elongation in 2 inches	18·0	21·0	19·0	19·0	20·50	22·5
Contraction of area	12·75	25·6	26·8	21·2	25·60	35·9

Average Results.

	Cupreous.	Normal.	Effect of Copper.
Breaking weight (tons per square inch)	46·55	44·63	+1·92
Elastic limit	25·00	25·20	−0·20
	Per Cent.	Per Cent.	Per Cent.
Elongation in 2 inches	19·30	20·66	−1·36
Contraction of area	21·38	27·56	−6·18

Series No. II.—Copper, 0·889 per Cent.

	Cupreous.	Normal.	Effect of Copper.
Breaking weight (tons per square inch)	49·4	48·0	+1·4
Elastic limit	27·1	24·8	+2·3
	Per Cent.	Per Cent.	Per Cent.
Elongation in 2 inches	23·0	21·0	−2·0
Contraction of area	37·0	32·0	+5·0

Series No. III.—Copper, 1·286 per Cent.

	Cupreous.	Normal.	Effect of Copper.
Breaking weight (tons per square inch)	42·2	41·6	+ 0·6
Elastic limit	28·0	23·4	+ 4·6
	Per Cent.	Per Cent.	Per Cent.
Elongation in 2 inches	23·0	26·0	3·0
Contraction of area	35·0	39·5	- 4·5

Not strictly comparable. (See Analyses.)

Unannealed Rail Heads.—Series No. IV.—Copper, 2·00 per Cent.

	Cupreous.	Normal.	Effect of Copper.
Breaking weight (tons per square inch)	49·7	39·7	+ 10·0
Elastic limit	35·9	22·1	+ 13·8
	Per Cent.	Per Cent.	Per Cent.
Elongation in 2 inches	21·5	27·0	- 6·5
Contraction of area	35·4	41·0	- 5·6

Annealed Rails.

	Cupreous.		Normal.	
	Large Head.	Web.	Large Head.	Web.
Breaking weight (tons per square inch)	43·9	51·1 5·05	39·6	44·00
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Elongation in 2 inches	23·0	17·0–16·0	24·0	25·0
Contraction of area	32·0	37·1–42·4	36·3	46·30

Average Results.

	Cupreous.	Normal.	Effect of Copper.
Breaking weight (tons per square inch)	47·35	41·80	+ 5·55
	Per Cent.	Per Cent.	Per Cent
Elongation in 2 inches	19·75	24·50	- 4·75
Contraction of area	35·87	41·30	- 5·43

The elastic limit was taken by dividers in every case.

Open-Hearth Steel.

A single charge of acid open-hearth steel was experimented upon in the same manner as those from the Bessemer converter. It was divided into two parts when fluid, and copper ingots were added to one part sufficient to yield 0·46 per cent. copper.

The following are the analyses of the steels made:—

Chemical Analysis.

	Cupreous.	Normal.
	Per Cent.	Per Cent.
Carbon	0·310	0·320
Manganese	0·614	0·614
Silicon	0·028	0·030
Sulphur	0·090	0·090
Phosphorus	0·069	0·069
Copper	0·460	0·021

Behaviour of the Steels at the Rolls.

Both parts were rolled into ½-inch plates.

When cogging down, the normal steel cracked and appeared to be slightly redshort, whereas, as before stated, the cupreous steel passed the rolling-mills without showing the slightest redshortness.

Tensile and Bending Tests.

Samples taken from various parts of the cupreous plates on analysis were proved to be homogeneous. The copper did not vary more than 0·01 per cent.

Test-pieces were shaped and tested with the following results:—

	Thickness of Plate.	Ultimate Stress. Tons per Square Inch.	Elongation. Per Cent. in 8 Inches.	Contraction of Area. Per Cent.
Cupreous	0·51	35·3	24	38·4
	0·52	35·1	21	40·3
	0·52	33·8	20	30·5
	0·51	34·9	22	42·8
	0·52	34·6	19	31·0
Normal	0·48	35·8	20	37·5
	0·49	36·3	22	30·9
	0·47	37·4	19	41·1
	0·48	36·6	20	32·3
	0·49	36·7	21	42·7
Average Results.				
Cupreous	0·52	34·7	21	36·6
Normal	0·48	36·4	21	36·7

The difference in the thickness of the plates is sufficient to account for the greater tenacity of the normal steel. The results show that the copper is without influence on the properties of the steel when cold.

A large number of pieces were tested by bending, but no difference could be detected between the cupreous and normal steels.

Weld Tests.

Both the cupreous and normal steels appeared to weld equally well, but this part of our research is not quite completed.

Conclusion.

The above results confirm most fully, as far as they go, the conclusions of Mr. Colby and Mr. Lipin. They show that copper has no more right to have the character of making steel redshort than carbon. They prove:—

1st. That between 0·5 and 1·3 per cent. copper has no deleterious effect on either the hot or cold property of steel.

2nd. That a very large amount (2 per cent.) makes the steel more liable to be over-heated.

3rd. In small quantities it slightly raises the tenacity and the elastic limit, but, unlike phosphorus, does not sensibly make the steel liable to fracture under sudden shock. Like carbon, it reduces the power of the steel to extend under stress, but this is not pronounced when the quantity is small. The effect is more marked when large quantities are present.

4th. That if the evidence of the open-hearth steel trial can be confirmed, copper, instead of producing redshortness, has the contrary effect of changing redshort steel into steel which will roll without cracking.

The President, in moving a vote of thanks to Mr. Stead, said that the paper would be discussed at the meeting in Glasgow, and therefore there would be plenty of opportunity for investigators to confirm or controvert Mr. Stead's arguments.

The vote of thanks was unanimously accorded, and the following paper was read:—

A COMPARISON BETWEEN
AMERICAN AND BRITISH ROLLING-MILL PRACTICE.

By WILLIAM GARRETT (Cleveland, Ohio).

The condition of the iron and steel trade in Great Britain to-day is attracting a great deal of attention. The supremacy so long held has been lost, and large quantities of foreign raw and finished material are being imported. Nevertheless, we have it on the authority of Sir Lowthian Bell and Mr. C. Kirchhoff that Great Britain can produce pig iron as cheaply as the United States. The imports of tin-plate bars, soft steel billets, plates and strips, indicate, therefore, that there is something wrong with the British method of making Bessemer steel ingot and rolling it into billets.

Blooming Mills.

As my remarks are addressed exclusively to English members of the Institute engaged in rolling-mill practice, I will begin my comparison with the blooming or cogging mill.

I understand Great Britain to be the birthplace of the Ramsbottom reversing-engines and reversing blooming mills. America, in its early history of making Bessemer steel, adopted the three-high system, and no two men have done more to perfect this system than Mr. John Fritz and his brother George, but since the advent of the four-inch billet, which is now so universally used in the United States, the two-high reversing mills have become almost universal, except for rail mill purposes. We simply copied what you had already done, and improved on it. The reason why a three-high mill is not considered so well adapted to make four-inch billets is, because when, as is often the case, a 6000 lb. ingot is used, the piece would be over 125 feet long when finished to a four-inch billet, and the lifting tables would have to be very long, in fact, too long to be con-

veniently handled, so with the exception of one or two mills which make some other product than billets, all four-inch billets are made on two-high reversing mills.

Logically, no other country should have been before Great Britain in adopting the four-inch billet as the standard size, and the fact is, that no country is more prejudiced against it. I will endeavour to explain why. All of your blooming mills are attached to finishing mills, upon which you make rails, structural shapes, large merchant bars, and small billets. Owing to this diversity of product from one mill there is necessarily a great deal of roll changing, and when changing rolls the whole system is stopped up to the making of Bessemer steel—everything standing still, time lost, money lost, and plant non-productive. In some places duplicate finishing mills are used in order to prevent this loss. If your cogging mills were adapted to make four-inch billets, as in the United States, and your small merchant and rod mills adapted to take a four-inch billet, all this loss would be obviated. The expense for an extra mill would also be unnecessary, as you could be making four-inch billets while changing rolls. In order to make say a two-inch billet, you must go through nearly all the motions of making a rail, except straightening, drilling, &c.; you must use the whole train and the same number of men; and a two-inch billet costs nearly as much to make as angle bars. You should also be able to make slabs suitable for making light plates, but you roll nothing but blooms suitable for the finished material for which your finishing mill is adapted. All that is necessary to make a four-inch billet and slabs, and any size of bloom for rails, &c., is a pair of rolls exactly the same as in general use on a blooming mill in the United States, with the necessary room for shearing and taking care of the billets. That it is desirable to find a market for what sizes you can make on your blooming mill while changing rolls is evident, seeing that your German competitors have recently adapted themselves to take a five-inch square billet, which they roll at one heat into wire rods; in fact, in some places they take a six-inch or seven-inch bloom and roll it into rods at the one heat. These blooms are sold at a lower rate than two-inch billets, as they are able to make those sizes on their blooming mill while changing rolls. This is leakage

number one, adding to the cost of all the material you make on your reversing blooming mills. Next is the time lost on account of the irregular way in which you keep your mill filled up with material. In the United States the greatest effort is made to find something for the blooming mill to do while changing rolls, and to keep the mill continually full of material. It is an acknowledged fact in regard to American mills that stoppages from breakages or some unforeseen cause are considered a misfortune by the management. Time lost through not keeping the mill full is considered a crime, and results in the immediate dismissal of the responsible party. Go to the manager's office in connection with any well-established steel plant and you will see on record a statement of what has been done in every department during every hour of that day, and the cause for every minute of lost time, if any. But it may be said by some that owing to close attention to this point the American mills and engines are better constructed than those in Great Britain to stand this, you may say, undue pressure. I may here say that the blooming mill holding the world's record for the production of four-inch billets per twenty-four hours—having produced 1260 gross tons in that time, at the plant of the Lorain Steel Company, Lorain, Ohio, from an eighteen-inch by twenty-inch ingot, weighing 5500 lbs.—is driven by a Galloway engine, and, in justice to the English engine-builder, I may add that no engines in the United States give better satisfaction than the three Galloway engines at the plant of the Lorain Steel Company.

Rail Mills.

I will now briefly consider your rail mills. Why is it that you do not make a larger tonnage in them? Is it because you do not desire to? If this is the case, I have nothing further to say on that point. However, if the reply is that you cannot find a market for any more tonnage, then I will ask why the American manufacturers ship so many thousand tons of rails to the foreign markets that were once yours, and underbid you to get orders? Why is it that you are making rails in every two-high reversing mill in your country, and in so doing not only losing your orders for rails, but allowing thousands of tons of tin-plate bars to come into your tin-plate districts, whereas,

if you could produce more rails in a given time, you would have more time to make tin-plate bars; and if your rail mills are not so well adapted as they ought to be for making rails or tin-plate bars, is it not better to remedy the evil than to lose trade? But are you taking out the maximum production from the rail mills you have, and have you the best adapted mills for making tin-plate bars? I question both, from what I have seen in this country and the United States. Do you keep your rail mill full of steel from six in the morning to six at night, as they do in the United States, where this is the rule and not the exception? If not, then that is one reason why you cannot get the same production, and manufacture as cheaply. Do you keep two bars in the roughing and two bars in the finishing at the same time? If not, then you differ from the American practice—this of course on three-high mills—and this is another reason why your output is not so great. But are your reversing mills adapted so that two bars can be handled in the same pair of rolls at the same time? Perhaps not, but such is the difference in conditions. It is my opinion that you try to roll too many different kinds of shapes and sizes on the one mill. For a jobbing merchant mill, in my opinion, no mill is more suitable than a reversing mill, and when the Lindsay coil-clutch gains the full confidence of the steel manufacturer, a reversing mill for rolling large sizes of merchant bars will become more popular than ever. However, in view of what is being done in the United States, it cannot be admitted that it is the best type of mill for rolling rails.

Tin-Plate Bar Mills.

One of the stock arguments of the British iron and steel manufacturer, when his attention is drawn to the large production of the American rolling mills, is as follows: "If we had such large demand for such special material as you have in the United States, we would not hesitate a moment to put in special mills and appliances to handle the material, and produce as much and as cheaply as you do." What about tin-plate bars? Prior to the year 1892, few, if any, tin plates were made in the United States, and yet that country was the largest user of tin plate in the world. For years previous to that time there were imported

m Great Britain from 300,000 to 350,000 tons of tin-plate r annum, and this was but 75 per cent. of what Great Britain ade. In Great Britain there was thus a demand for about 0,000 tons of tin-plate per annum, calling for approximately 0,000 tons of tin-plate bars every year. Was not that a fficient amount of special material, and enough to induce me one to put up special mills for making tin-plate bars? seems not, for if anything, the mills you make tin-plate ars on to-day (after losing nearly all of that trade) are better an they were when you had almost a monopoly in the anufacture of tin plate for the world; so you must confess at due diligence was not shown with a view to taking adantage of the favourable conditions at that time. What did our American cousins do, with the demand for tin-plate bars bout 100,000 tons per year less? Why, some of the best, if ot *the* best, machines there are in the United States for the rolling of steel are mills for making tin-plate bars, and to-day they re pushing their tin-plate bars in thousand ton lots right into our tin-plate districts. Among the most noted tin-plate bar nills in the United States are those at the following plants: he Duquesne plant of the Carnegie Steel Company; the National in-Plate Bar Mill at Youngstown, Ohio; the Bellaire Steel Company, Bellaire, Ohio; and the mill at Vandergrift lately owned y the Apollo Steel Sheet Company (all of which mills many of ou have seen). Each of these mills is of a special type, and rom the ingot to the finished bar—even to the placing of the atter on the cars—all of the work is done by machinery. The esult is, tin-plate bars are sold for $1 per ton above the cheapest teel product in the country, *i.e.* a four-inch billet (and in some ases even less). It is true that these mills cost a great deal to uild, but money is no object to the American manufacturer if e can but see a fair return. I must confess, from my experience and observation, that the British manufacturer is rather onservative on this point. With a large tin-plate trade, no ffort is being made to prevent foreign competitors shipping in-plate bars right into the country from a distance of 3500 miles.

Structural Steel Mills.

Structural steel calls for little notice, as I cannot see such a marked difference in the British and American methods. Indeed the Carnegie Steel Company roll all of their structural steel on the three-high system, while the Pencoyd Iron Works roll their material partly on the three-high and partly on the two-high system, and opinion is fairly evenly divided as to which is best and will make the larger tonnage. The practice in Great Britain and on the Continent is, I understand, to use the two-high reversing mill. Whilst with this system the cost of labour may be more, the yield of finished product is greater than with the three-high mill. The advantages and disadvantages thus appear to me to be evenly balanced.

Plate Mills.

It may seem strange to hear an American say that he believes a two-high reversing mill for rolling plates to be better than the three-high mill with the small roll in the middle, but I must frankly confess that such is my opinion—this, it must be borne in mind for plates five-sixteenths of an inch thick and above—and were it not that a reversing engine takes more steam than a positive running engine, I think there is no question of the advantages in favour of a reversing mill. I base my opinion on the following:—

First, there are no lifting tables required, which are very hard to keep up.

Second, if the three-high mill is better adapted to roll thin plates, the reversing mill is better adapted to roll thick plates. Placing a five or ten ton slab on a lifting table necessitates the waste of so much energy in raising and lowering the slab.

Third, a reversing mill is better adapted for the introduction of extra sets of finishing rolls. This adds to the life of the rolls, and gives a smoother surface to the plate.

But then it may be said, "Look at the enormous output of the American three-high plate mills, some of which have made over 10,000 tons of finished plates in a single month." To that I will reply, "Keep a two-high reversing mill as full of material as they do in the States, and your product will be no less; in fact, it

ought to be greater." See at any time during the day or night a three-high plate mill in operation at the Homestead Works of the Carnegie Steel Company. There, as regularly as the tick of a clock, the slabs are successively placed on the table which carries them to the rolls, as each plate is going through the last pass; in fact, the slab has often to be stopped to give time for the rolls to be raised to the proper place to suit its thickness. Adopt the same methods at some of the modern plate mills in Great Britain, and mark the increase in the output. In rolling a plate three-eighths-inch or half-inch thick from a well-heated slab on a three-high mill before it gets to the last pass or two, it is generally the custom to wait so as to finish the plate at the required heat in order to get the necessary tensile strength and a smooth surface. You will observe exactly the same conditions on a first-class two-high reversing mill. If this is so, whence comes the advantage so far as output is concerned? On a three-high mill plates must be finished in such shape as to suit the market. Indeed, I honestly believe that if some energetic American manufacturer ever puts in a two-high reversing mill with two stands of rolls, he will outstrip the present output of the three-high mill, for, while the plate is cooling to the required degree on the table of the finishing set of rolls, he will give the next slab two or three or more passes in the first set. Moreover, to say that the British workman cannot be as active and energetic as the American workman, if it is his desire, is entirely wrong.

Merchant Iron Mills.

Before touching directly on your merchant bar practice, both iron and steel, I will give you my opinion as to the principal cause of your falling behind. It is simply because, up to the present time, you have had no competition. Look back at your record for the past ten years as regards the manufacture of iron and steel. True, there has been a slight and steady increase —in fact, you have not fallen behind your own achievements, but have failed only to keep up with the achievements of others. How many new iron and steel plants have been started in Great Britain since the year 1890? Few of importance, if any. How

many millions of money have you spent during that time on improvements? I may be wrong, but I will venture to make the assertion that during the past ten years all of the British iron and steel manufacturers together did not spend as much money on improvements as the Carnegie Steel Company did in two years. And why not? Is your ingenuity and energy exhausted? You, who were at one time the greatest manufacturers of iron and steel in the world? I cannot believe it. It has been simply because you were not compelled to do so; you could do well enough without. Who gave to the world the Bessemer, the basic, and the Siemens processes? Great Britain. Who showed how to make bar iron, wire rods, hoops, &c.? The British. Who gave us the continuous mill? Bedson, an Englishman. Who gave us what is known as the Garrett system of making wire rods? Great Britain and Belgium. Who gave us the best type of heating-furnace for heating steel billets, which is now almost universally used in the United States and is almost a curiosity in Great Britain? Allen, an Englishman. Who gave us the idea of a successful reversing mill? Ramsbottom, an Englishman. I might go on indefinitely. Yet, having given us all this, we Americans have improved on them to such an extent that they can scarcely be recognised, and we are to-day using them as a means to compete with you in the markets of the world. Yet, when it was suggested to the management of some of these plants that by the introduction of some American methods a great saving in money could be made, the reply has been, "Why should I? I made over 30 per cent. on my capital invested last year, and am satisfied with that." And at that same time they were rolling by hand three-quarter-inch round bars in about sixteen feet lengths, making about 10 tons per turn, had one engine—which appeared to have been designed by Watt himself—driving four or five antiquated mills, eight or ten shears, and I don't know what besides. Can any one admit there is competition in a country where such conditions exist? To be able to pay dividends in this enlightened age under such conditions is a libel on progress, science, invention, and ingenuity, and is an imposition and a grievous and unnecessary tax on the consumer. I may say here that all of your iron merchant mills are not

like that, but this is no fancy dream sketch, and not the only mill of this type in Great Britain. While you have some first-class mills for making iron, the main fact which I wish to convey at the present time is, that having rolling mills of this type, which can pay dividends, means that you have had little or no competition. One of the best guide mills in the United States for rolling iron is what is called the Williams mill, in operation at Youngstown, Ohio. This mill consists of a sixteen inches roughing train and a five-stand ten inches train, and in it is rolled a box pile five inches wide and six inches high, containing over 60 per cent. scrap and less than 40 per cent. top, bottom, and sides. This is rolled into three-quarter inch rounds in 100 feet lengths, and the output is from 40 to 50 tons per turn. As I understand it, you have very few mills of this type in Great Britain—in fact, even in the United States this Belgian mill is not so popular as might be expected from its merit of being able to take a large pile and roll it on a slow speed train when the pile is short and "dumpy," and of finishing it, when the bar is long, on a train having a faster speed.

Merchant Steel Mills.

As far as I can see, up to the present time no steps have been taken in Great Britain in the direction of building mills specially adapted for rolling merchant steel. In the United States, during the past two years, great attention has been paid to this. First of all, it was found that the Allen type of furnace could be used for heating steel billets, whilst it was entirely unsuited for the purpose of heating an iron pile. The adoption of this type of furnace has reduced the cost of heating over 75 per cent. in labour alone, and it has been proved that the economy in fuel is equal to the Siemens heating furnace. An Allen furnace can heat 135 tons of four-inch billets in a single turn, and if the Laughlan patented arrangement for dropping the billets out of the furnace on to the conveyer is adopted in connection with it, only one heater, two helpers, and a man to push the billets into the furnace, are required to operate two furnaces, which have averaged over 200 tons per turn for a whole month, the total cost per ton for labour being about 6d.

As this is the maximum output on rod-mills, it is but fair to state that when using the furnace for merchant mill purposes, where the output is less, this cost may be increased to 9d. per ton. Without the Laughlan dropping-out arrangement the cost is about 25 per cent. more. When we realise that this type of furnace is of English origin, and that any there may be in England are looked upon as a curiosity, this is something to be greatly wondered at. This is one of the main agents in connection with the cheap production of wire rods and merchant steel. Next, we have continuous trains to do away with the hard work of roughing down. A four-inch billet is rolled into, say, a three-quarter-inch round, with but four men at the entire mill, doing all the work necessary to deliver it on to the hot-bed. This includes one man to look after the continuous train. Merchant mills of this type, starting with a four-inch billet, have produced as high as 445 gross tons of one and one-eighth-inch finished square bars in twenty-four hours, and have produced over 8000 tons in a single month. The sizes rolled on these mills are from three-inch to one-inch wide flats, any thickness, and from one and three-quarter-inch to a half-inch rounds and squares. The mills of course are best adapted for the middle range of sizes. On another type of mill for making merchant steel they start with a billet 30 feet long on all occasions, and vary the size to suit that of the finished bar. This billet ranges from one-and-a-half-inch to three-inch square, and in some cases the bars are finished about 300 feet long. Too much credit cannot be bestowed upon the Morgan Construction Company of Worcester, Mass., for the fine point of perfection these mills have been brought to. Their hot-bed arrangement is a work of marvellous ingenuity—165 tons of two-and-a-half-inch and a half-inch is the best record I know of, but the mill has a still greater capacity. As to the merits and demerits of starting with a billet, say under four-inch square, I would say that since, apart from the fact that the capacity of the mill is controlled by the capacity of the furnace, as only one can be used, a four-inch billet is sold in the open market in the United States for $1 per ton less than the smaller size billet, and the total tonnage labour to roll a four-inch billet into a finished bar is less than

$1. As it does not take more fuel to heat the same than is required to heat a smaller billet, it seems to me that merchant steel rolled from a four-inch billet is delivered on the hot-bed—so far as tonnage labour is concerned—at the same cost as the one-and-a-half-inch or smaller billet is delivered at the heating furnace. On mills of this type a merchant bar can be finished and placed on railway waggons for less than 14s. per ton above the cost of the billet. This includes loss, fuel for power and heating, and the cost of everything required to produce it. When the time comes when pig iron will again be sold for 37s. 6d. per ton in the United States, and four-inch billets for 58s., giving with 14s. per ton added for cost of conversion to merchant bars, 72s. per ton as the net cost, then not only Great Britain, but also Europe, will have what may be called competition. As so far no effort has been made in Great Britain in the direction of putting in mills specially adapted to roll steel, I have nothing from which to draw a comparison except the mills for rolling iron bars, on which steel is also rolled, but I will say here that it is impossible to devise a mill having the same advantages as the American mill I have described to roll both iron and steel.

Hoop Mills.

If I were to be asked what I consider the finest rolling-mill machinery in the world, I would without the least hesitation say the continuous hoop mill at Youngstown, Ohio, designed and built by the Morgan Construction Company, of Worcester, Mass. On this mill results are obtained which have been thought impossible, and for nicety of adjustment and precision of relative speeds it is, in my opinion, the finest display of ingenuity in this line. This mill also has derived its main wonderful features, such as flying-shears and coiling-machine, from a Welsh engineer, Mr. Edwards. Fancy a one-and-a-half-inch billet, 30 feet long, and weighing 225 lbs., entering the first set of a continuous train and coming out of the last set seven-eighths of an inch wide by No. 20 gauge. After the hoop comes from the rolls it is laid by a folding process on a slow-moving table, and the only one to touch the hoop with a pair of tongs is a boy, who picks

up the first end and enters it into the reel, which coils the hoop up as neatly as a ribbon. The hoop is afterwards cut automatically into the required lengths for cotton ties. The output of this mill is about 45 gross tons of seven-eighths of an inch No. 20 gauge hoops, in a single turn. It is impossible to describe this remarkable rolling-mill machine. However, mainly owing to the impossibility of obtaining a uniform size throughout the entire hoop when finished, this mill has not met with the favour one would expect. For cotton ties, or hoops, which do not require to be of an exact gauge throughout, it may be all right. Be this as it may, the fact is the American Steel Hoop Company, or their predecessors, have built two hoop mills since this continuous hoop mill was built, and neither of them is of the continuous type throughout. The most popular type of hoop mills are those having a continuous roughing-train and looping finishing-train of four sets of rolls, on which it is a common thing to make 45 tons in a single turn of one-and-three-quarters-inch and one-and-a-half-inch by 18 or 19 gauge, or about 30 tons per turn of seven-eighths of an inch by 20 gauge cotton ties. As to how much better these results are than those obtained in Great Britain, I will leave you to judge. From what I understand and have seen, you still have the old-style hoop mills of ten or fifteen years ago, and where your practice is most lacking is in the means to take care of the hoop as it comes from the last set of rolls. It is no trick, on a first-class hoop mill in the United States, to roll one-and-a-half-inch No. 19 gauge in 200 feet lengths, and the piece will run out the entire length without being touched. Then, again, you roll iron and steel hoops on the same mill, which prevents the adoption of certain improvements, in particular in connection with the heating of the billets.

Mills for Rolling Strips for Tubes or Skelp.

In regard to strips, the finest mill there is in the United States for this purpose is a three-high universal mill built by the Garrison Foundry Company of Pittsburg, Pa., for the Lukens Steel Company, on which mill they roll from ten-inch to thirty-six-inch in width. They have but the one set of rolls

three-high. I understand this mill is giving very good results, but the manufacture of this class of material, strange to say, has not been developed to any extent even in the United States. One reason for this is, that it is but lately that the consumer has become reconciled to the use of steel pipe, the material for which alone will permit of any extensive and marked improvement in the method of manufacture. However, with what there is, American practice is far ahead of British. On an ordinary ten-inch train, over 60 tons of four-and-a-quarter-inch by ten-inch strips have been produced in a single turn, and between 60 and 70 tons of from six-inch to ten-inch strips per ton is a common thing on a sixteen-inch mill. This refers to steel strips. I understand that in Great Britain you pay double the price for rolling strips that you do for bar iron, whereas in the United States less is paid than for rolling bar iron. Special rates are allowed the manufacturer by the Amalgamated Association to pay men rolling strips. This is no doubt owing to the fact that at one time nothing but cut nails were used in this country, of which over 6,000,000 kegs were made in a year, calling for over 300,000 tons of twelve-inch to fourteen-inch strips. This made the rolling of strips so familiar and common, and competition became so keen between the cut and wire nail, that reduction after reduction took place, which was naturally felt by the strip and skelp makers; and most of these nail plate mills, as they were called, are rolling strips to-day. As the methods of rolling strips are about the same in both countries, I will close the subject by making the prediction that within the next five years more improvements will be made in the direction of improving the present method of making strips than in connection with any other process in the steel business, as the demand for them is growing greater every day, and a production of from 250 to 300 tons of strips per ton, varying from ten to twenty-two-inch wide, will be a common occurrence.

Wire Rod Mills.

I touch upon the subject of wire rod mill practice last of all, because the striking developments and results by the American rod mills speak for themselves, therefore I will not take up your

time with this at present, but will refer you to an article published in the *Iron Age* of February 22, 1901, to another article on the history of the four-inch billet, published in the *Iron and Coal Trades Review* of March 8, 1901, and to the address of Charles H. Morgan before the 1900 Meeting of the Society of Mechanical Engineers, which give the Morgan Construction Company due credit, in a very modest way, for all they have done to improve rolling-mill practice. I will merely add that while there are two well-defined types of wire rod mill in use in the United States, viz. the straight continuous and the improved Belgian types, the latter being commonly called the "Garrett" mill, judging the popularity of both these types of wire rod mill from the number of each in use, the continuous mill would be of little moment were it not for the mills of this type in operation at the works of the Washburn & Moen Company (now belonging to the American Steel and Wire Company) at Worcester, Mass., and at Waukegan, Ills., which of late have been perfected by Mr. F. H. Daniels, chief engineer of the American Steel and Wire Company, to such an extent as to become quite a formidable rival to the looping type. Indeed, it is only justice to say that Mr. Daniels is the only man who ever designed and constructed a continuous wire rod mill that could successfully roll more than one rod at the same time, and his last effort—in the wire rod mill at Waukegan, Ills.—is a masterpiece in that line. This mill starts with a four-inch billet, and the output is nearly equal to that of the best looping mills, about 350 tons to the double turn, whereas the Morgan continuous mills, starting with a one-and-three-quarter-inch billet, produce about 150 tons per double turn.

I will now proceed to express my views on the rod mills of Great Britain. I understand that at Middlesbrough there is a straight, continuous rod mill which has been in operation for some time, but for some reason or other, recently, another mill was put in, but it was of the Belgian type. Messrs. Richard Johnson and Nephew, of Manchester, have a rod mill partly of the continuous and partly of the looping systems. They, through Bedson, were the pioneers of the continuous mill, but have changed from the straight continuous mill to part Belgian. The roughing train is continuous, and has vertical rolls in all cases, to reduce

the ovals to a square. This is the finest mill of its kind in the world, and the manner in which these vertical rolls are driven show remarkable engineering skill. But why have vertical rolls, which prevent you from rolling more than one bar at a time, when the "twist" guide will do the work just as well, and you could have all of your rolls horizontal? There is a four-high mill at Warrington which is much more complicated than a good Belgian mill. On this mill the bar, when it is square in cross section, is carried by means of what might be termed a split pipe from the top two-high set to the bottom two-high set, the latter set being speeded up in proportion to the reduction. As this is accomplished by a curved guide on all Belgian trains, with a saving of labour and with no complication, and as the output of some of the Belgian mills in Germany is not reached, the advantages presented by this mill are open to question. Then there are some of the very oldest types of rod mills in Europe; and in order to show how far you are behind in output at least, I will make the assertion that the four best rod mills in Great Britain, during the month of January, did not produce as many rods as one of the wire rod mills in the United States, which during that month produced 10,230 gross tons of No. 5 rods: indeed I might make it five of your best mills and be safe. Here we have five different concerns—five mills, five crews of men, five rollers (skilled men), five heaters (skilled men), paying the rollers, say 25s. per day each, or £6, 5s., and the heaters 15s. per day each, or 75s., making a total of £10 for each turn's work, instead of one roller £2, 10s., and one heater 25s., or £3, 15s., or over 75 per cent. less, not to speak of the balance of the men; and I wish it to be understood that, in my opinion, the best men at the rod mills I ever saw are those who work on your present mills in England, so it is not the fault of the men. The question might be asked, "If each of those five rod-mill owners had a rod mill of that capacity, what would they do with such a production of rods?" This I do not know; but if the present method of making rods is persisted in, the time will soon come when you will not make any rods at all. When British steel-makers find some means of supplying a cheaper two-inch billet, to meet the price of which the American steel-makers may not find it to their advantage, then they will deliver wire rods to England at a figure less than you

are now paying for two-inch billets. Is there no remedy, will Great Britain give up the wire business? she who was mother of that business, and has taught the world how to [illegible] wire? I think not, and believe there is a remedy which [illegible] be eventually adopted. Supposing the five largest users of [illegible] rods in Great Britain were to combine and erect a large first-[illegible] rod mill, keeping their business just as it is, and each party [illegible] stock in the new rod-mill deal in proportion to the amount [illegible] rods they would use, they could treat this new enterprise [illegible] entirely new organisation from their present wire-drawing [illegible] and choose a site for it not far from a shipping port on [illegible] the east or west coast. Then let us see how they would [illegible] with a view to securing their raw material in the shape [illegible] billets. So far as their supply from Great Britain is concern[illegible] conditions would be the same as to-day, but they could not [illegible] get their billets from the Pittsburg district, as they are [illegible] at the present time, but could also draw their supply from [illegible] Tennessee Coal, Iron, and Railroad Company, of Birmingham, [illegible] who are situated but a short distance from the seaboard; from [illegible] Maryland Steel Company, of Sparrows Point, Maryland; and [illegible] the Dominion Iron and Steel Company, whose plant is at Sydn[illegible] Nova Scotia, or 1000 miles nearer Liverpool than New York. No better source for a supply of billets could be had. W[illegible] keen competition comes, the Dominion Iron and Steel Compa[illegible] who can make the cheapest pig iron in the world, will always [illegible] able to make steel billets at a low cost. This same scheme [illegible] be applied to all who now make rivets, bolts, &c., or those [illegible] make tubes or pipe, and want soft steel billets to make their str[illegible] In fact, if your raw material, such as ore and coal, is becom[illegible] scarce, and you can find a better market for your coal, selling for steam purposes rather than to manufacturers of pig iron [illegible] steel, who during times of competition must have cheap coal, I [illegible] see no better scheme. Why import ore, which has over 50 [illegible] cent. of useless matter, when you can import billets on which there is but from 5 to 6 per cent. loss from the billet to [illegible] wire rod, merchant, or steel strip. This rule can be applied [illegible] those who use strips for tubes. Indeed, if the British [illegible] and steel makers do not follow the example of their Ameri[illegible] cousins and combine, and then only manufacture their respect[illegible]

material at the most advantageous points for shipment, and use the most economical method in manufacturing, the manufacture of iron and steel will in time become a lost art in Great Britain. Should that day ever come, then the fulfilment will become possible of the prophecy made by Lord Macaulay, when he said, "Some traveller from New Zealand shall, in the midst of a vast solitude, take his stand on a broken arch of London Bridge to sketch the ruins of St. Paul's."

DISCUSSION.

Mr. W. H. Bleckly, Hon. Treasurer, said it was seldom that they had an orator such as the author of the paper to address any of their meetings. In introducing his subject, Mr. Garrett had first made the important and bold assertion that the supremacy which Great Britain had so long held in the iron and steel trade was lost, and this he supplemented by stating that "there was something wrong with the British method of making Bessemer steel ingot and rolling it into billets." They could each form their own opinion as to whether either one or both of these statements were in accordance with the facts. It was true that subsequently some polite things were said about the Britisher of the past, but nothing of the kind with regard to the present. The author then indulged in a long panegyric on the 4-inch billet, and informed them that no country was more prejudiced against it than Great Britain. That was really too amusing. We in this country were always glad to use a 4-inch billet when it was suitable and economical; but it was needless to say that we should not try it for rolling into $4\frac{1}{2}$ square bars or $\frac{3}{16}$ half ovals. These were, of course, extreme illustrations, but numbers of others would occur to his hearers. Mr. Garrett's advice to avoid roll changing was rather belated; this was a thing which British ironmasters had been striving to do for the last forty years, to his knowledge. Then the question was asked, why the Americans shipped so many thousands of tons of rails to foreign markets which were once ours, and underbid us to get orders. He would answer that later on. Our critic then asked, "What about tin-plate bars?" and "What did the Americans do with that demand?" He promptly answered himself by saying that the best machines in the United States were pushing their tin-plate bars in thousands of tons right into our tin-plate districts, adding that no effort was being made to prevent competitors shipping tin-plate bars into this country from a distance of 3500 miles. He then insinuated that it was not an unusual thing in this country to see $\frac{1}{4}$ round bars rolled by hand in 16-feet lengths. Really this was grossly unfair. Mr. Garrett must have

been visiting a museum. They had rolled $\frac{3}{4}$ round bars at Warrington every week for forty years or more, and never rolled a single bar except by guide. It seemed useless, however, to pursue details further. Mr. Garrett had been good enough to explain a great deal of American machinery and to impress upon them how much superior it was to our own. With regard to some machinery he was not going to dispute this; but they were, however, quite as anxious to learn as Mr. Garrett was to teach them. Mr. Garrett had passed in review almost every kind of machinery used in the manufacture of iron and steel in the United States, and they agreed with him that this machinery was very important and effective; but he had studiously avoided referring to a certain class of machinery which in America was much more important and necessary to the success of the American iron and steel trade, and that was the machinery of the tariff. Mr. Garrett told them how to make cheap hoops, certainly not of uniform thickness throughout; but this seemed of little consequence in America, though very important in England. What would Mr. Garrett say when he (Mr. Bleckly) told him that, in spite of our being, in his opinion, so much behind America, there was to-day an order being executed in this country for 1000 tons of cotton ties, which were absolutely being delivered at the other side of the Atlantic by the so-called stupid and out-of-date Englishmen, although the duty on that article in America exceeded £2 per ton? From that fact they were bound to argue either that the Americans could not make their hoops as cheaply as we could, or that the American maker's profits were at least £2 per ton; or, to use Mr. Garrett's own words, "they were imposing a grievous and unnecessary tax upon the consumers," those consumers being their own countrymen. He knew that controversies of this kind were not customary in that room, but Mr. Garrett had been allowed to attack the British ironmasters in such a violent fashion, that in fairness he was entitled to speak in their defence. Did it come well from Mr. Garrett to accuse British ironmasters of putting a tax on consumers when they were ready and willing to sell hoops at £2 per ton less in America than consumers in that country were compelled to pay the American manufacturer? Mr. Garrett concluded his paper by recommending them to sell their coal for

steam purposes and give up the manufacture of pig iron and steel. He was absolutely amazed that any member of that Institute should stand up in that room with such words in his mouth. He might tell Mr. Garrett that he had bought Lincolnshire pig iron at less than 30s. at the furnaces, and that he was told by the makers of that pig iron that they did not lose money at the price. If necessary, the same thing, and perhaps better, could be done again. In conclusion, he might remind Mr. Garrett that the American tariff machine was constructed on the "continuous principle." He recommended him to bestow some of his advice at home, and to suggest to the engineer of that machine the propriety of introducing reversing gear.

Mr. Edwin Tonks said that although he had been for thirty years practically engaged in the manufacture and design of rolling plant, that was the first occasion on which he ventured to address that distinguished Association. He would like to say that, as Mr. Carnegie had given a new commandment a little earlier that morning, so Mr. Garrett had now given another new commandment with regard to the 4-inch billet, and he would say a few words on that subject. Mr. Garrett seemed to think that the 4-inch billet was the great want in this and other countries, and just the thing they ought to go in for in order presumably to give the Americans a still better chance. He gathered from Mr. Garrett's paper that some of his main points (but all bearing on one another) were the following:—First, that it was of great importance in all large steel plants to be able to keep the cogging-rolls fully employed on saleable billets during the time that the finishing-rolls were stopped for changing. Secondly, in the majority of American modern two-high cogging-mills it was not convenient to make billets direct from the ingot in the one pair of cogging-rolls of a less size than about 4 inches square, for which reason it would be a good thing for them if all merchant-bar and guide mills would, or could, agree to work up solely billets of that standard size. Thirdly, Mr. Garrett himself stated in his paper that his own countrymen in their most successful merchant-mills did not find it expedient to adhere to one fixed size of billet, and it was equally known to every practical mill manager in this country, that in order to deal with the innumer-

able variety of sections and bars turned out in the British mills, billets of various sizes and weights were indispensable. From the above premises it was important that cogging-mills in their spare time should be capable of turning out billets of various and smaller sizes than the minimum 4 inches square, at present obtained from the main pair of cogging-rolls, and without appreciably adding to the cost of working, the number of men engaged, or, of course, interfering with the changing of the rolls in the finishing portion of the mill.

It appeared that Mr. Garrett was under the impression that British steel manufacturers had hitherto overlooked those important points; but he could assure him, from a long practical acquaintance with most of the leading steel-makers of this country, that it was a subject to which they had given much consideration. The owners of single 2-high cogging-mills both in this country and America naturally found it an awkward matter to alter their existing arrangements, but where it was possible, the best plan to meet the requirements of the trade seemed to be that which was already being adopted by one or two leading firms in this country. The plan was substantially as follows: The cogging and finishing mills should be in one line instead of apart or tandem-fashion; four pairs of rolls should be combined, instead of only three, as in existing plants. Those four pairs of rolls should be arranged generally in the following order:—First, the usual pair of cogging-rolls with the top roll arranged to rise and fall as required to suit ingots of the larger or smaller sizes, and drafted to reduce them to blooms of a convenient size for the main cogging-rolls. These rolls should form holes to suit girders and other large sections which have to be dealt with in the finishing rolls. A strong bloom shearing machine should be fixed in the usual way in conjunction with these cogging-rolls to crop the bloom ends, or to divide the blooms if necessary, before passing on to the succeeding rolls. The second pair of rolls should have grooves suitable for producing all sizes of marketable billets, varying, say, from $5\frac{1}{2}$ inches down to 2 inches square, and also flattened billets of various widths. In this pair of billet rolls the top roll is not required to lift up and down as in the former case, but should be fixed with the grooves true to those of the bottom roll, thereby pre-

venting the twisting of the billets which occurs in attempting to roll those of smaller sizes in cogging-mills proper, where the top roll has to be set loosely for moving up and down. The housings of these billet rolls, however, should be furnished with underneath balance gear and top electrical or steam screwing gear, so as to be ready at any time to deal with the roughing down of extra large joists and other sections requiring more than one pair of roughing rolls. The third pair would be the usual roughing rolls for large sections, with balance gear and top screwing gear. Fourthly, there come the usual pair of finishing rolls. The reversing engines for driving the above-mentioned four pairs of rolls should be two in number, one pair working at the cogging end of the train and the other at the finishing end. The axes of all the bottom rolls and pinions should be in line with each other so that in case of emergency the whole four pairs of rolls, or any less number could be driven by either pair of engines. It is an advantage to have the cogging-engines furnished with differential speed gearing, so that after the blooms have passed from the cogging to the billeting rolls, the working speed may be greatly accelerated to accommodate the lighter work and longer billets, without the necessity of increasing the number of strokes per minute of the engines. Several leading firms in this country have cogging-engines provided with this differential speed gearing, which is very simple and effective, being actuated with the utmost ease and expedition by means of a small hydraulic cylinder. The pair of engines at the finishing end of the train would of course be direct acting, without the intervention of any gearing.

Duplex skidding gear should be provided on the front and rear sides of the train, so that the work at the cogging and finishing rolls can be going on at the same time without intermission. It would be seen that by having the cogging, the billet, and the roughing and finishing rolls all in one line instead of some distance apart, the workmen were all conveniently near together and could assist each other. The mill, as described above, was of course intended for producing bars and sections of all the various kinds called for in the British markets. A mill for dealing exclusively with one particular type of section such as rails, or otherwise, would of course be specially designed,

perhaps somewhat more in accordance with American practice, to suit the circumstances.

Sir LOWTHIAN BELL, Bart., Past-President, said that there were two or three questions connected with the subject under discussion in which he and every one else had been very much interested. He would say, firstly, in answer to the accusation —which he did not assert was made use of unfairly by the author, whose paper was a most excellent one—with regard to the indifference of manufacturers in this country to what was done in America. He should have thought the fact that the Institute visited America in 1890 to see what had been done might be accepted as a *primâ facie* proof that English manufacturers were not indifferent to what had been done there. Now, of course, they were in a totally different position to that of the American ironmaster who was about to erect an entirely new works. He might choose to go to the expense of £25,000, say, in order to make steel or iron, as the case might be, as cheaply as it could be made, so far as mechanical means were concerned. But the English ironmaster stood in a somewhat different position, inasmuch as if he spent £25,000 in order to effect that saving, he would have to sacrifice the £25,000 he had already laid out. Therefore, the American manufacturer had the advantage there. With regard to the accusation of indifference on the part of the English manufacturers, he could only state—what was well known to the President as well as to himself—that nothing had stood in the way of those in the Cleveland district in regard to reducing the cost of manufacturing pig iron, at all events, for the last thirty years. All the old furnaces, all the old heating apparatus, and so forth, had to be done away with, and other furnaces and heating stoves provided; and they had done that, feeling that they were acting in the best interests of their position by adopting the best means then known of conducting the work. In America the manufacturers continued improving their appliances. Among other things, electric power was largely introduced with great advantage. He had been struck with the novelty and the perfection of the means employed, and had invited one of the most distinguished rolling-mill works and blast-furnace engineers that he knew of over

from the United States to the Clarence Works. That engineer had spent, he was about to say days, but thought weeks was nearer the truth, at the Clarence Works, and at the end of his inspection had given it as his opinion that, having regard to what had been already expended there, he could not recommend them to follow the American example. He had the most profound admiration for what their friends on the other side of the Atlantic had done, and at the Clarence Works they had done their best to keep themselves up to the American standard; but the cases were so different that he had been unable to go to the length of making all the changes recommended by Mr. Garrett in his paper. He did not know that anything more occurred to him in answer to Mr. Garrett, or in relation to what had been advanced in defence of English practice. As to the paper itself, he had listened to it with feelings of very great interest indeed. It must be remembered that the amount—something like five shillings per ton—which might possibly be saved by following the example of the Americans, was more than counteracted by the cost of transporting steel or iron in any form from the United States to this country. He scarcely saw his way as yet to make the radical changes proposed, but every means which could be learned from their own experience, or from that of manufacturers in other countries, would be utilised in the construction of all new works undertaken.

Mr. Walter Dixon said that as one who had had the pleasure of inspecting many of the American works three years ago, and who understood a little of the spirit of Mr. Garrett's paper, he should like to say a word or two. He felt there would be no lack of discussion of the technical details of the alleged differences in steelworks practice between America and our own country, and with that fact he was not able to deal. He thought, however, that they would lose one of the most important lessons to be drawn from Mr. Garrett's paper if they failed to note the bare and astounding fact that it was even possible that such a paper could have been written. References were often made to the practice which was current in America when the Institution last visited the States, but he ventured to think that no one who had not been there during the last few

years could possibly realise the immense strides and improvements which had recently taken place. It was an old saying that "we are the heirs of all the ages," and the Americans, by taking advantage of this, had in a wonderfully short time raised up a formidable rival to an industry which had its home in our own country. Nobody was more ready than the Americans to acknowledge—and to acknowledge gratefully—the benefits and help they had received from our own country, and inasmuch as they were not hampered as we were by vested interests, they had been able with their new and rising industries to avail themselves of every item of modern practice. Sir Lowthian Bell had, in mentioning this, struck one of the main points of difference between the past and future possibilities of America and our own country. With existing works it must always be a question, in considering improvements, how far one could afford to disband working plant which, while not being of the newest type, could scarcely be considered obsolete and useless. At the same time there were instances, and amongst these was that of Vandergrift, which Mr. Garrett had mentioned in his paper, where Americans seemed to face matters somewhat differently to ourselves. He (Mr. Dixon) had the pleasure of going over the works there and had seen the old works exchanged for new ones. He had been told there by a gentleman well known to many members how only a very few years before they had been able to make money as well as tin-plates in their old works, but that the money-making days there were past, and hence they also had gone past their old works and had put up new ones. He had said, "There are the old works, they represent $600,000, and if the concern is of any use to you, you can have it. It is of no use to us." The puzzle to every Britisher had been and was, how the Americans made money in the steel industries. So far as his friends in Scotland were concerned, he believed the general impression—until a recent date—had been, that money was not made in the actual manufacture but by their combinations. A recent law case, however, had dispelled that idea. Another point to contend with was, that Britishers, belonging to an old and wealthy nation, had perforce become conservative. In America things were different. Theirs was a new country, and they were not

conservative. Further than this, the older we got the more conservative we became, and while both in this country and in America there were brilliant examples of men past their prime of life who were active and ever on the alert, still, they were the exceptions and not the rule, and so long as elderly and old men were retained at the head of our concerns, it was doubtful how far we could maintain our position, with other disadvantages round us, in the face of the Americans, who put their young men into trusted positions, not only to dictate, but to carry out their policy. He had made a statement in a paper which he had read before the West of Scotland Iron and Steel Institute three years ago, that the general impression obtained from visiting the works in America was, that men under thirty-five years of age largely controlled and moulded the policy of the industries and trades. Undoubtedly this was so, and its effects had been felt in the past, and he believed would be felt more in the future in a thousand and one ways.

Before going to America he had seen plant erected in this country on lines which were represented as modern American practice. He was somewhat surprised to find no such plant at work in America, and learnt from inquiries that it was already considered obsolete and had been replaced. This indicated that the same time had been occupied here in considering and erecting such a plant as had sufficed in the country of our rivals to condemn it and to erect improved plant. This he thought was evidence that they must not be content to view this matter and deal with it at the ordinary "jog trot" pace, but must be as active and as alert as our opponents. We had nothing to be ashamed of in the past, nor should we have in the future, as soon as we actually realised what conditions we had to face.

Much, however, of an unpleasant nature may arise, depending on the time it took us to realise and to act upon the new conditions which this formidable competitive rival was forcing upon us. Besides the points mentioned, there were other difficulties which we had to face, amongst which perhaps the labour question was one of the most formidable; also that of our local resources, but with these he would not deal. It was however clear to the most casual observer that the "morale" of

the American workman seemed to be entirely different to our own. As to the reasons of this, there may be a diversity of opinion, but as to the fact there could be none.

Mr. J. M. While said that Mr. Dixon had intimated that English manufacturers were lacking in enterprise and energy, but he was sure that neither he nor the members generally could endorse that criticism either with regard to men or managers. He had read Mr. Garrett's paper, and would probably have done better if he had made a note of the heads of his remarks, but would endeavour to make his points clear. Mr. Garrett had spoken favourably of the various mills of America. They quite admitted that they were excellent. Every engineer or mill manager who had been to America knew they were excellent, that they had excellent machinery throughout, and that the Americans did the very best that could be done with the resources at their disposal. He must take exception, however, to several things which Mr. Garrett had stated. In speaking of blooming-mills, the author stated that they had the same mills as English manufacturers, and that they had simply copied what we had done and improved upon it. He had had the pleasure of visiting America five years ago, and seeing practically all the blooming-mills, and was bound to say that he did not see any better mills there than were to be found in several places in England to-day. Cogging-mills in some cases were driven direct; in other cases they were geared; but he did not see a cogging-mill at that time which was making 4-inch billets. Mr. Garrett proceeded to say that the cogging or blooming mills made 4-inch billets, and that it would have been better if Great Britain had adopted that as the standard size. Farther on the author stated that our not making 4-inch billets in our blooming-mills caused a considerable leakage. He thought the Dowlais Company at their cogging-mills made 4-inch billets fourteen years ago. The first thing he had done when he went to Barrow ten years ago was to ask his directors to put down the plant for 4-inch billets, and it was put down then, and on no occasion did they allow the Bessemer blooming-mills to stop while the changing of finishing rolls took place.

Farther on the author stated that it was an acknowledged fact in America that stoppages from breakages, from some unseen cause, were considered a misfortune by the management. He thought there were no works where a stoppage of any kind was not considered a great misfortune. Further, if one went to the manager's office, Mr. Garrett said that one would see a report stating what had been done in different departments at different periods of the day, showing that the managers took some interest in the works. It was now some twenty-two years since he was at Dowlais, but he knew that it was the custom of the managers there to receive the reports of the work of every mill every two hours. He had instituted that in his own firm, and thought that every manager of any importance in this country was doing so. He did not see that the most modern mill in America was at all superior to the Dowlais mill, or to the Barrow cogging-mill, except that the latter had been put down some years ago, and its gear was somewhat slower; but it was not so slow as to be of any disadvantage. At Barrow and other places there was a certain amount of material which it was possible for them to convert into pig iron and finished steel. To put mills up which could deal with a larger quantity of raw material than they possessed would be quite a loss of expenditure in capital and also in labour. He admitted that the mills of America turned out larger makes, but it did not follow that on that account it would be a more economical way to work in England —far from it. With all his knowledge, which was very full, of the American mills, he could say that he would not have the best mill in America in place of the Barrow mill. Mr. Garrett apparently thought there was more advantage to be gained out of larger makes than was understood in this country under the very different conditions existing. At the time America sent a large amount of material into this country last year, they were probably paying for coke 10s. per ton, while English manufacturers were paying 33s. per ton, and that difference was more than sufficient to pay the cost of the carriage from the works in America to the works in Wales. He thought that America had a great future. How far it would affect England in the long-run it was impossible

to say; but whatever advantages America had, they were not so much obtained from the mills as from her natural products. America had large quantities of iron ore low in silica and high in iron, and an abundance of cheap fuel. And again, their products were carried at a very low rate on their railways. While English manufacturers paid nearly one penny per ton per mile for what was conveyed by railway, the Americans paid only one-sixth of a penny. Protection had undoubtedly enabled Americans to build the very excellent mills which they had. He thought the advantage which was possessed in America by quick-driving was due to the ore, it being low in silica, which enabled them to smelt it at their furnaces very easily, and they put down excellent plant for doing so. Iron made with low silica ore has the considerable advantage that it must be worked very speedily. A Bessemer shop in England takes twenty-five minutes to blow a heat owing to the nature of their iron, whilst the Americans must blow theirs in nine minutes. They were forced to drive their Bessemer, and therefore erected such mills as would take their Bessemer product while hot.

Mr. W. CARSON said that although he belonged to one of the incriminated trades, he was not disposed to reply to Mr. Garrett's strictures upon the methods adopted in the wire trade, because things which were stated here had a habit of getting across to the other side of the Atlantic, and there forming a starting-point for those clever gentlemen to use the experience gained here to our detriment. But while admitting and agreeing with Mr. Garrett as to a standard type of billet, he might mention that Mr. Garrett's mills ran on the same size of billets and the same weight and quality of billets from January 1 to December 31. He need not say that that was not the class of work which, on the whole, they followed, although it suited the demand in America. There was another point which had struck him arising out of an incident which had happened when he visited Mr. Garrett at the time when that gentleman had just completed his first improvement in the mills at Cleveland, Ohio. That was in 1882. A man had come up to him and shaken hands with him. He did not recognise the individual, but he was informed that he had

been one of his puddlers. He asked him how he got over there, and he was told that the man had left England at the time of the strike, the strike being with regard to the six-heat trouble. He (Mr. Carson) had asked how many heats were dealt with in America, and was told that there were six or seven sometimes. Then he asked why he would not do that in England, and the man replied, "Well, it is like this: when I got over here it was like tumbling into a mill-race, and I had to go with the stream." He had never forgotten that illustration. There was no doubt an enormous amount of money in the United States which its 76,000,000 people poured into the laps of the manufacturers through the tariff to pay for these improvements — for making up the $600,000 loss which had been mentioned, for instance. The American public were very willing to find the capital for the steel and iron masters, and for every trade which had protection, in order to bring machinery up to date. In England the manufacturers had to put their hands into their own pockets, and, as Sir Lowthian Bell said, if they destroyed £25,000 worth of plant, they also had to find the means for replacing it. In the newspapers one always heard the complaint that the manufacturers did not do this, that, and the other, and the great cry had been for technical education. That was all very well. It should be pressed as far as it could be pressed; but he wanted to know whether the first condition that would enable them effectually to educate technically their working-class population must not be a desire on the part of that population to be educated technically. His friend in America had tumbled into a mill-race. He wanted to know if, as regards British labour in the experience of any one of them, there was any "mill-race"? It was not his experience. There were no better workmen either in rolling-mills or anywhere else than the British workman, but the idea of the British workman was totally different from that of the American workman. The American workman worked for all he could get; the English workman worked to get so much a week, and getting it he was satisfied. In many instances, however, his deliberate limitation of output, his impatience of all control, his contempt of shop

discipline, and his artificial restrictions in other respects discouraged the British employer and seriously affected the trade of this country.

The meeting then adjourned until May 9.

Mr. W. R. WEBSTER (Philadelphia), continuing the discussion, pointed out that no comparison had been made of the quality of the finished material rolled on the modern rapid-running mills with that produced on the old slow-running mills. This was of too much importance to be overlooked, as it explained, to some extent, why the slow-running mills, with their small output, were still in use in many places. In the case of rails, one of the members, a few years ago, summed up the case pretty much as follows. He said: "Formerly the hardness, toughness, and good wearing properties of our rails were given by the mechanical work of rolling the steel at a low temperature on our slow-running mills, but now we give the hardness by the chemical composition and squirt the rails through the rolls." The force of this statement was appreciated to-day better than ever, and it was generally admitted that the best steel might be rendered almost worthless by being finished at too high a temperature in rolling, and also that the proper heat treatment in connection with the mechanical work in rolling had as important a bearing on the properties of the finished steel as its chemical composition. But regard must be had to the proper reductions in each pass in rolling, as too great reductions would bring out the second heat in rolling and the material would not be as good, no matter what the final finishing temperature was, as it would have been if moderate reductions had been used in connection with the proper finishing temperature.

The increase of carbon had been greatest for the heavier sections of rails (and in some cases carried too far). This rendered the steel much more sensitive to injury from too high a finishing temperature. The manufacturer's difficulties were still further increased by the thin metal in the wide flanges of these heavy rails cooling off so much quicker than the large compact mass of metal in the heads of these rails. This prevented the work of rolling on the heads from being carried to a temperature

low enough to break up the coarse grain structure and produce the good tough steel so much desired. Taking everything into consideration, the rolling of satisfactory high carbon 100-lbs. steel T rails was the most difficult problem that the steel mills in America had to contend with.

The 100-lbs. T rails rolled in America were as good as those rolled in any other country, but they were not giving as satisfactory results as the lighter sections. Yet when these heavy rails were re-rolled to lighter sections they gave very satisfactory results, the change being due to the breaking up of the coarse structure by the annealing action of the slight heat for re-rolling, this heat not being sufficient to again form the coarse grain. There was also the further beneficial action of the rolling at this low temperature. All this had caused quite a reaction to set in, and now the greatest attention was being paid to the finishing of heavy rails at a lower temperature. The mills were endeavouring to do this without interfering with their large daily output. The Carnegie Steel Company were using an intermediate cooling bed, where several rails were held with the head of one rail in contact with the flange of the rail next to it, until they reached a low enough temperature for the final pass.

Other methods had been suggested and tried, but in all cases up to the present time it was the thin metal in the flange of the heavy T rails that controlled the finishing temperature. The engineers recognised this difficulty and were disposed to meet the manufacturers half way. The American Society of Civil Engineers were going to discuss, at their Annual Convention next month, the advisability of appointing a committee on rail sections to consider putting more metal in the flanges of the heavier rails. The committee on rails of the American Railway Engineering and Maintenance-of-Way Association, in their report of March last, advocated putting more metal in the flanges of the heavier rails.

It was of course of the greatest importance to have a trustworthy check on the finishing temperature of our rails, and one had been suggested which seemed to have many advantages on account of its simplicity. It was the amount of shrinkage that took place in a thirty-foot rail from the temperature at which it was cut at the hot saw until it reached the normal temperature. After

this had been determined by careful experiment, it would no doubt be embodied in American rail specifications.

Doubtless Mr. Garrett would admit that the mill of the future should embody all the good features of the old slow-running mills as to the number of passes and low finishing temperature, with the large or larger output of the present rapid-running mills, and perhaps he might have some suggestions to offer as to how this could be brought about in the different classes of mills referred to by him.

Mr. W. R. Webster in a subsequent note stated that in 1894, in his paper before this Institute on "The Relations between the Chemical Constitution and Ultimate Strength of Steel," he gave a table showing the correction found necessary on account of finishing temperature for different thicknesses of material, and said :—" When rolling heavy steel plates, trouble is often caused by finishing them at too high a temperature, which gives a material with crystalline fracture, poor reduction of area, and poor bends. In order to guard against this and control the finishing temperature, we use very light draughts in rolling, and produce as good results in heavy plates as in the light ones. Too much importance cannot be given to the heat-treatment of steel. Mr. H. M. Howe's recent experiments on the subject are of the greatest value, and it is to be hoped that they will be continued on a larger scale in connection with the work of rolling and forging."

Mr. W. H. BLECKLY, Hon. Treasurer, asked if he might be allowed to say a word of a personal nature. Since reading over Mr. Garrett's paper again, he had noticed a statement that there was a four-high mill in Warrington which was much more complicated than a good Belgian mill. Mr. Garrett in his wisdom might consider that mill was complicated, but he did not know as much about it as he (Mr. Bleckly) did. Complicated or not, he would undertake to say that that mill in the course of twelve hours would make fewer cobbles either in rolling two rods or three rods at a time than any mill in America. And that when the Americans took off their duty, many English firms besides his own would be prepared to enter orders for small No. 6 wire rods, and deliver them at the other side of the Atlantic at

American prices, and he did not think they would do so without making a profit.

Mr. FINLAY FINLAYSON said with regard to Mr. Garrett's remarks as to the plate-mills, he thought, instead of saying that British mills were equal to Americans, he ought to have said that they were better with regard to plate-rolling. The principal fault that Britishers had was, that they did not keep their mills full. Mr. Finlayson had put down a mill at the Stockton Malleable Ironworks about thirteen years ago, and they had been taking from 1350 to 1450 tons per week regularly out of this mill. There were other mills which had been put down since, and he was quite confident that they could take 2000 tons a week out of a modern British mill. Certainly there was a mistake in the driving of ship-plate mills—they were too slow for ship plates. There was only one case that he knew of where they were driving direct, and they could easily take from 150 to 160 tons per shift of twelve hours out of that mill. Another thing was, that in the three-high mill in America they could not make the same surfaces on the plate as we could do; in fact, it would be hard to get them to pass the inspector in this country. He would like to ask Mr. Garrett about the skelp-mill, as he called it. Mr. Garrett said that they were rolling with a universal three-high mill up to 36 inches wide. How did Mr. Garrett keep those plates from buckling when working at 10 or 11 wire gauge? Then Mr. Garrett said that the three-high mill was the best for rolling hoops. He recollected that in their district they had a three-high mill and the ordinary old-fashioned two-high mill with balanced roughing rolls, and strange to say in the pull-over the two-high mill was better than the three-high mill for output. In the three-high mill they had to change the roughing rolls for the various sections, whereas in the two-high mill they never required to change the roughing rolls at all. He had taken as much as 50 tons per shift of twelve hours out of that two-high mill. The fly-wheel of the engine was not strong enough to drive any faster, or he could have done more. It was a 24-inch mill. He should like some information with regard to the three-high mill. Another point was, that in this country hoops had to be put through planishing rolls, as the tube-makers in this country would not take the

hoops here as they were rolled in America, that is, with the same surfaces.

Mr. J. P. Bedson said, that as the continuous mill had been mentioned in the paper, he thought it would not be inappropriate for him to say a few words on the continuous system. He did not wish in any way to depreciate what Mr. Garrett had said or what he had done in America. Wonderful work had been done there, and he was quite ready to acknowledge it. At the same time he had naturally a strong feeling for the continuous system for wire-rod rolling, as he was the son of the inventor. He was sorry that Mr. Garrett was a little misleading in his statement in the paper, where he depreciated the continuous mill, and referred to the mill at Middlesbrough, for which he (Mr. Bedson) was responsible. He stated, "I understand that at Middlesbrough there is a continuous rod-mill which has been in operation for some time, but for some reason or other recently another mill was put in, but it was of the Belgian type." This continuous mill was designed to roll 300 tons a week of No. 6 rods, and not No. 5, as rolled on the Garrett mill. No. 6 small, it would be readily understood, was a more marketable article than No. 5 from a wire-drawer's point of view. That mill was doing from 350 to 400 tons a week at the present time, rolling a 2-inch billet weighing over 3 cwt. to No. 6. This billet had never to be lifted in its entire weight by the men in the mill; for when he stated that one roller and one helper and a hooker, who could be done away with, were the only three men on the mill, he did not think that was very bad practice. As to Mr. Garrett's statement that the Belgian mill had been put down in the works, this was perfectly true, but it had been on the carpet for eighteen months, and had not yet displaced the continuous mill, which was still running. This continuous mill delivered the No. 6 finished rod at an equal temperature to that at which the billet went into the mill, so that the finished rod was as soft as possible with the particular class of material they were rolling. There was no chance of its being cold-rolled. With regard to the rod-mills referred to at Messrs. Johnson and Nephews, he might say that although he had not had anything to do with them for a considerable time, one of the old mills which was put in

in 1866 was running to this day, the only alteration being the addition of a few rolls with larger grooves to take a 2-inch billet, instead of the 1½-inch, as originally intended. A further remark he had to make as to Mr. Garrett's idea of distribution from a large mill. That placed in a convenient central situation to serve various wire-drawing concerns would be very nice, and would, no doubt, be very nice in America. He reminded Mr. Garrett that in this country the railway companies would not carry wire rods 600 miles for 6s. per ton, nor would they carry them, as they did in Germany, 400 miles for 4 marks per ton.

CORRESPONDENCE.

Mr. FINLAY FINLAYSON (Coatbridge) supplemented his remarks at the meeting, and stated that he did not consider that Mr. Garrett had grasped the conditions under which work has to be carried on in this country. Speaking of rails, for instance, in the United States they could keep on rolling the same sections from week to week, whereas in Great Britain it was considered a very good run if they could keep the mill on a single section for twenty-four hours. In some cases the rolls might have to be changed twice in one shift, and where frequent changes were necessary, the work of changing a two-high mill was very different compared with that of changing a three-high mill. In fact, the present system of rolling rails was the most suitable under the conditions which exist in this country. The Americans would very likely find this to be the case when they came to invade our territory. As Mr. Garrett admitted, the opinion as regards structural mills was fairly evenly divided, and it might be said that rails have to be produced in this country under the same conditions which governed the rolling of structural work.

It was impossible to agree with Mr. Garrett when he said that the cost of labour was more with the two-high than with the three-high mill. If the mill was properly designed, there was no doubt that the advantage was on the side of the two-high reversing system.

The system under which the plate mills in this country were worked was far in advance of that in use in America. In a reversing mill it was easier to roll a five-ton slab than a five-hundredweight one, and the breadth and length could be better regulated than was the case on a three-high mill. The usual practice was to roll plates in lengths of from 50 to 70 feet, keeping them to breadth and cutting them to length in the same way as bars. With vertical heating furnaces and well-designed tables on the mills, the writer had made plates at a labour cost of 5d. per ton for heating and 8½d. per ton for rolling. The most expensive part in the present system of plate-making was the shearing.

With regard to merchant mills and the production of ordinary merchant sections, he thought Mr. Garrett wrong in saying that we were behind in this country. In an ordinary 12-inch guide mill in the Coatbridge district it was usual to take from 35 to 42 tons of 1-inch round iron per shift of twelve hours. It was doubtful whether they could do as well as this in America. But of course, as far as rod-rolling was concerned, the manufacturers of this country were not in it. The works referred to by the author must be strangely antiquated, as all shears and other items were now driven separately. About twenty-five years ago it might have been the rule, but for the last twenty years rolling by hand in the Coatbridge district had been entirely done away with. Here again, however, the conditions were different, since the mills must be arranged for rolling either iron or steel.

Mr. S. S. Horsfield thought that the members of the Institute were very much indebted to the author for this most valuable paper; it ought to be an incentive to the British steelmakers, or, as he plainly put it, they would be left behind.

There was no doubt that the American rolling mills were a long way ahead of those in this country, but the case was scarcely so bad as the author painted it. Take the cogging or blooming rolls; the author said, "Why not adopt the design of the American cogging rolls?" That did not seem at all necessary. The three cogging mills with which the writer was familiar had rolls of as good a design as the American ones. Perhaps English mills were not so powerful, but with a pair of rolls that would take a 16-inch square ingot or 20-inch by 14-inch ingot, and make

any size of bloom down to a 4-inch billet, or slabs from 18-inch by 4-inch to 7-inch by 2-inch, much more could not be expected.

These same cogging mills worked direct from the mills making structural steel, and when making angles, channels, &c., the make reached anything between 150 to 200 tons every twelve hours. When changing rolls in the finishing mill the cogging mill was kept busily cogging slabs for sheet mills and 4-inch billets for small bar or rod mills. Therefore it was not necessary in this case for the whole of the plant to stand idle while changing the finishing rolls, as the author said.

It might also be mentioned that at one of the works where such a mill was working, it was nothing unusual to roll angle bars 300 feet long; in fact, the writer had rolled bars over 400 feet long.

Rail mills, whether three-high or two-high reversing, should be made very powerful, and should be specially designed for rails only, to work economically, but it was a matter of opinion whether the three-high or two-high reversing was the best. From the point of economy perhaps the advantage lay with the three-high mill.

The author was right in stating that we roll tin bars in our two-high rail mills, but that scarcely constituted a jobbing mill. For tin bars the three-high mill was certainly the most economical. With a powerful mill and a good supply of steel the make might be anything above 500 tons per twelve hours' work. There were three-high mills working tin bar in this country, but it was to be feared they were too light for large makes.

The author asked whether our mills were kept running full during the twelve hours' turn. The answer to this was "No." One of the greatest drawbacks and complaints heard in steelworks in this country was either "short of steel" or "short of steam."

In the case of the three-high mills in America, which dealt with two pieces in the roughing rolls and two pieces in the finishing rolls at the same time, it would be interesting to know whether each set of rolls were driven by separate engines. Perhaps Mr. Garrett would enlighten us on this point.

The author also mentioned the Lindsay friction clutch. In the writer's opinion, this clutch would never supersede the reversing engine, although it certainly did the reversing of the rolls admirably. The shock given to a mill was, however, not in the reversing, but when the rolls gripped the piece, and in a constant

running engine the shock was severe when the work was heavy, as in a cogging mill. With a reversing engine this did not occur. As regards plate mills, he thought it was as the author said; the three-high plate mill was the most suitable for thin plates, and the two-high reversing for thick plates.

Would the author state if the roughing or breakdown rolls in the American plate mills were of steel, and whether the rolls had a constant supply of water running on them? Had they two sets of hard or finishing rolls, and was only a certain size and certain weight of plate rolled in a certain mill? It was a very easy matter to make large outputs in some mills, when it was possible to pick the orders by splitting up the specifications. Further, in speaking of large makes, the number of mills on that class of work should be stated, so as to show the average tonnage of the lot.

The statement that we rolled three-quarter rounds by hand on our iron merchant mills was probably incorrect. The writer had heard of it, but had never seen it. It was most likely rather ancient history.

It was doubtless true that a large quantity of the machinery in British iron and steel works ought to be put on the scrap heap, and better appliances substituted, otherwise there was danger of our being left behind, and of the steel trade of this country becoming a thing of the past.

Mr. Garrett, in his reply, regretted that he had not heard all of the statements which had been made that morning, but he would take an opportunity of replying in full when he received a record of what had been said. He would only touch now upon some of the main points as briefly as possible. Mr. Webster had asked him to say something upon the benefit of rolling the material cold. That the rolling of steel at a low temperature was very beneficial in many cases was pretty well known, but there was one point to which he wished to draw their attention, and that was that owing to the increase in section of the rails demanded in the United States, on account of the increased weight of cars and locomotives, they did not wear so well, and it had been found that by rolling them colder the life of a rail was increased. What had they done to remedy this in America?

What had the Carnegie Steel Company done when they found that out? Did they cut down their product? Did they stop the whole mill by delaying the process of finishing the rail to allow it to cool? No. They devised a means whereby they could get a rail finished at any desired temperature without decreasing the product of the mill. They believed in large output, and they rolled their rails almost cherry-red, if necessary, and that without decreasing their daily product.

Mr. Bleckly had spoken about his mill, and also about the quality of the rods in America, and a good deal had been said about the inferiority of the plates. Thousands of tons of rods had been imported into this country from America in the past, besides thousands of tons of plates, steel bars for rivets, and strips for tubes; and when the steel trade recovered its normal condition in the States, they would export thousands and thousands of tons more. Yet it would still be claimed by some that the American product was of an inferior quality. Who were the largest users of steel in the world? The United States. Who used more wire rods than any other country in the world? The United States. In the United States they made rods which were drawn down to wire and made into nails. England did the same. England made fencing wires, America did the same. England made spring wires, America did the same. England made wire for weaving, America did the same. In fact, America produced wire for every purpose for which England produced it, except crucible steel wire. Ninety per cent. of the rods used for wire were made on what are called Garrett rod mills, and not 10 per cent. of the million tons or thereabouts which were made annually on those mills were perfectly round, and about 50 per cent. were one to two sizes out of the round. Yet the people of the United States appeared to live comfortably and happily, and used the finished material made from those imperfect rods to good purpose. The British wire manufacturer had yet to learn that in order to obtain economical results it was not absolutely necessary to have a perfectly round rod, except for some very special purpose, such as screw and wire rods made from high carbon wire. In reply to Sir Lowthian Bell, he would say that any remarks made by him must be received with respect and attention, and he was very much gratified to hear for the first time

his reasons why pig iron could be made so cheaply in England, and also the reason why he felt so sanguine as to the future of the iron and steel industries of Great Britain. He would quote the following from his remarks bearing on this point: "Nothing had stood in the way of those in the Cleveland district in regard to reducing the cost of manufacturing pig iron;" again, he said: "All old furnaces, all old heating apparatus and so forth, had to be done away with, and other furnaces and heating stoves provided; and they had done that, feeling that they were acting in the best interests of their position by adopting the best means then known of conducting the work." Now this was simply nothing more or less than what he (Mr. Garrett) had suggested that the British iron and steel masters should do with their rolling-mills, but Sir Lowthian Bell apparently did not preach what he had practised with such good effect, for he demurred, on the part of the iron and steel masters here, against scrapping an old rolling-mill that might have cost £25,000 in its original construction.

He was very glad that Mr. Finlayson had endorsed what he had said about plate-mills; he was glad that there was at least one man in the room who agreed with him.

Yesterday Mr. Bleckly said that he doubted his statement that $\frac{3}{8}$-inch round rods had been rolled by hand in this country in 16-foot lengths. He saw that done in 1898, not in a museum, as had been suggested, but on a mill in a works in England. He might say he had never seen a rolling-mill in a museum, though he had seen many in Great Britain which ought to be there. He could not afford to get up before that body of men, which was composed of the brightest and most scientific men in the world, so far as the manufacture of steel was concerned, and make an absolute misstatement. Mr. Bleckly had said that there was a company in England which had an order for 1000 tons of cotton ties to be shipped to the States. These were, after paying the duty, sold at £2 below the price that the American makers had asked. He would ask if the members of the Institute were aware that in America they were making cotton ties for delivery to some places which were as far distant from Pittsburgh as the middle of the Atlantic. Were they aware that the freight in some cases was seven and eight dollars per ton more than from Pittsburgh to Liverpool? Were they

aware that ships which took cotton to Great Britain were glad to take anything back as ballast? The 1000 tons mentioned was a mere fraction of the demand for cotton ties in the United States, which was about 45,000 tons a year.

Mr. Bleckly had affirmed that in their works they rolled all ¾-inch round by guide. He wished to say in reply that he had made a statement in his paper with regard to first-class mills for making iron, thereby intimating that he knew they had in this country some excellent mills for rolling iron bars. He also knew that the ¾-inch round was rolled by guide in some mills, but he called in question the lack of competition, when some ironworks could still roll these by hand, making 10 tons per turn, and still pay large dividends. He wished to say that he had seen the works in which Mr. Bleckly was interested, and he frankly admitted that their mills were the best in Great Britain for rolling iron bars, with the exception of those at the Waverley Ironworks at Coatbridge, Scotland, where a good deal might be learnt about the rolling of iron.

In his remarks Mr. Tonks first questioned the advantage of using a 4-inch billet. He seemed to think that he had laid too much stress on its value, and that it did not suit all sizes required in the trade. In his article entitled "The History of the Four-Inch Billet" it was stated that owing to the cheapness of these billets means were used to make a 7-inch flat from that size of billet, and that as small as ½-inch round and square, and ⅞ by $\frac{3}{16}$ flats, were rolled from a 4-inch billet. In fact, he stated that since it cost 4s. per ton more to make a 2-inch billet than it did to make a 4-inch billet, and since 4s. would pay the tonnage labour for making 4-inch billets into finished bars, hence a finished bar, so far as the tonnage labour was concerned, could be delivered ready for shearing and shipment for the same cost as 2-inch billets delivered at the furnaces. For very small sizes he was prepared to design a mill, and in fact they were building one in the United States, that would make ⅞-inch 20-gauge hoops and as small as ¼-inch round, starting with a 4-inch billet. He claimed that the happy medium in the size of steel billet, to give the best and cheapest results in the rolling of wire rods and merchants bars from the ingot to the finished bar, was a steel billet 4 inches square. Mr. Tonks seemed to doubt the merits of

billets of this size as compared with those of smaller billets. He had given an elaborate description of a rolling-mill, apparently not in use; this, however, was in his opinion somewhat beside the question, for they were discussing a comparison of existing mills, and not of those to be built in the future.

He would make the following statement in support of his suggestion that they should import steel billets instead of ore containing 50 per cent. of useless foreign matter. The idea was no insane one, and was certainly not entitled to the scathing rebuke which he had received for suggesting it in that hall. A short time ago a Scotch ironmaster, who for years had supplied a large proportion of bars for the rivet business of the Clyde shipyards, ascertained that some thousands of tons of steel rivet bars had been delivered from the United States in the vicinity of Glasgow at a lower price than what he could deliver them at, when buying the billets necessary for the purpose in Great Britain. Did he sit down and cry, "It was all owing to the cheap raw material in America"? Or did he rail against the tariff and American protection? Not at all. He at once took measures to find the cost for which he could get 4-inch steel billets delivered in Scotland from America, calculated what it would cost to roll those billets on his present mill into round bars suitable for making those rivets, tendered for a 2000 ton lot, and got the order. He bought those billets from the United States and made a good profit on the transaction, and if he had had the improved American mill, about which some scornful remarks had been made, he could have made 8s. per ton more profit. He would draw no moral from that incident, the conclusions were plain enough. All fair-minded men, he thought, would admit that in this case half a loaf was better than no bread.

One of the most remarkable statements he had ever heard had been made by Mr. While, namely, that he would not have the best rolling-mill in America in his works, and gave as a reason because it produced too much. If that theory was correct, then the Carnegie Steel Company had all along been working on the wrong line, in spite of the fact that in all the annals of history of iron and steel no company had made more than they in the last twenty years. Between 1895 a they sold their products at a lower rate than any o

in the world, yet they not only encouraged but demanded the maximum production from every furnace or mill that they had. Mr. While had also said that it was generally the case in Great Britain that the blast-furnaces could not supply pig iron fast enough to keep the Bessemer plant and rolling-mill fully occupied. That had always been the condition in the Carnegie Steel Company's works. They never, up to the present time, had enough pig metal from their own blast-furnaces to keep their Bessemer and open-hearth plant in full swing, and in spite of the fact that they have been for the last ten years continually building blast-furnaces there has not been a single year in which they did not buy pig iron largely. Not long ago they bought 50,000 tons from outside parties. What for? Not to pile up and keep in stock, but to use so that their finishing mills could be kept going to the fullest capacity. What was more surprising still, a small output was advocated by Mr. While in spite of the fact that only a little over two years ago many thousand tons of plates, billets, &c., were shipped to this country from America at a time when all works here were employed to the utmost extent, and the consumer was literally starving for iron and steel materials. It was further stated that owing to the low silicon in American pig iron they were compelled to blow their Bessemer heat in nine minutes. Why compelled? That was a consummation greatly to be desired by the American steel master. They were only sorry they could not blow a heat in five minutes. They aimed at getting their pig iron low in silicon so that they could have a short blow, and in their quick way of handling the material they could use pig iron with less silicon than Great Britain could. Mr. While was of opinion that the British blooming-mills were as good as any of the American blooming-mills, and stated that twenty years ago in Dowlais they rolled 4-inch billets on their blooming-mill. He (Mr. Garrett) wondered why it had been discontinued. Was it a failure? It surely was not a success, or they would have continued doing so up to the present time.

It was easy, Mr. Carson had stated, for an American to use a 4-inch billet for rolling wire rods because they always made the same size of wire rod. Seeing that Mr. Carson had not been in the United States since 1882, if he mistook not, he

could hardly blame him for that erroneous statement. The fact was, that on the latest type of rod mills they were rolling from 1-inch round and all sizes between down to No. 5 rods, and they could roll any weight from 120 lbs. to 300 lbs. if desired. That could not be done on the rod mill in Warrington nor upon that continuous mill that Mr. Bedson spoke of. Mr. Carson laid great stress on the labour troubles. Was not that an argument in favour of adopting automatic machinery to do away with labour? That was one of the main reasons why the Americans were so far ahead in this line. The high wages and the trouble they had with their men compelled them to adopt some plan to do away with manual labour. Regarding home protection, it seemed to him that there was a tendency, though it was attempted to disguise it at present, to appeal for protection as the remedy for their troubles, but it would not avail much to any nation which had more of an export than an import trade. They could only obtain the trade of the markets of the world by delivering their material at a less cost than their competitors. In conclusion, he thanked them most cordially for the attention and courtesy they had extended to him, and if they desired he would be pleased to take an opportunity of replying to any points which he might not have heard that day.

The PRESIDENT said that, on behalf of the Institute, he proposed a vote of thanks to Mr. Garrett for his interesting paper. They were exceedingly indebted to their friends from over the water, whether they were competitors or not, when they came to give the result of their experience. They might differ from them in their opinion as they differed from them sometimes in practice; but the energy, the industry, the education, and the enlightenment which had developed the trade in America had been exceedingly wonderful. The weakest had to go to the wall unless they were wakened up sometimes; but he trusted they would all take a lesson from the details which had been put before them so fully, and, so far as he could judge, so honestly by the author of the paper.

The vote was carried by acclamation, and the following paper was then read:—

THE USE OF HYDRAULIC POWER IN THE MANUFACTURE OF IRON AND STEEL.

BY R. M. DAELEN (DÜSSELDORF).

THE treatment of iron and steel, whether in a cold or hot state, frequently involves the application of pressures of such magnitude, that their transmission by any other means than that of water under high pressure is impracticable. It is therefore a matter of no surprise that the use of high-pressure water as a source of motive power is largely on the increase, while at the same time, owing to the advance of electricity as a direct-acting power for driving auxiliary machines, the employment of low hydraulic pressure is being rapidly abandoned. The limit between low and high pressure may be said to lie at about 1400 lbs. per square inch, but the real advantage of the latter begins only at a much higher point.

There has hitherto been a general tendency to keep hydraulic pressure comparatively low, for the sake of avoiding the difficulties which are apt to arise in designing the pumps, valves, accumulators, piping and packing; cost of maintenance is also a source of trouble when very high pressures are used. On these accounts chiefly it has been usual not to exceed 550 to 700 lbs. pressure on the square inch. It will, however, be generally admitted, that if the pressure could with safety be considerably increased, certain advantages might be secured, not the least of which would be a reduction in the size of cylinders and rams.

The following are the three best means of attaining a higher pressure:—

1. To abandon the use of pumps with many complicated valves, accumulators, long pipe systems, and apparatus for the distribution of high pressure.
2. To increase the number of cylinders in the presses in order to reduce the diameter.
3. To substitute for the leather stuffing-box some kind of packing which would cause less friction.

The author himself successfully solved the first of these problems by the introduction of the multiplicator or intensifier. In saying this, he does not lay claim to have been the first inventor, but states that, without any previous knowledge of the appliance, he recommended the practical use of this principle to Messrs. Breuer, Schumacher & Co., at Kalk, near Cologne, and in co-operation with them designed and perfected an intensifier which has now been widely adopted, and is to-day acknowledged to be the most suitable apparatus for producing high-pressure water. Indeed, it may be reckoned to have secured a lasting place among the tools for metallurgical work.

The first application of it, about twenty years ago, was to the driving of a bloom shears (Fig. 1, Plate IV.). The intensifier was placed above the hydraulic cylinder, and the piston-rod of the steam-cylinder was arranged to enter directly into the former, producing there an increase in the hydraulic pressure in the proportion of about 1 to 100.

After thoroughly studying a scheme for applying it to shears for cutting large ingots, it was found that this form of construction would be too high for most of the rolling-mill buildings, which at that time it was usual to make very low. On the other hand, the double-acting arrangement would use too much steam. It was therefore decided to adopt the arrangement shown in Fig. 2, Plate V., which was successfully carried out, and has since been employed not only for bloom shears, but for numerous other purposes besides. The establishment of Breuer, Schumacher & Co. has supplied in all about 270 hydraulic presses of various kinds on this system, and other firms have taken up the principle so far as it appeared possible without infringing the patent.

The final arrangement of the intensifier proved to be possessed of other unlooked-for advantages; thus it was found that the piston, when actuated from below, does not require any special power for the back-stroke, but nevertheless it acquires a considerable speed (up to seventy strokes per minute); it became, moreover, possible to place the intensifier, which is quite separate, at any desired distance from the press, an arrangement which is sometimes extremely convenient for local reasons. Another unexpected advantage was manifested in the immediate stopping of

the piston the moment that the entering steam is cut off, which cannot be so easily effected if the piston is made to work in the reverse direction, owing to the necessity of having to counterbalance the effect of gravity each time.

Undoubtedly the best field for the application of high-pressure water is afforded by the forging press, some of which have already been built capable of exerting a pressure of 15,000 tons, and as there is every probability of a further advance in this direction, it would not be out of place to examine for a moment the mechanism of a forging press, and the conditions which are required to be fulfilled. The resistance presented by the object to be forged varies very much according to its cross-section and temperature. For instance, a soft and very hot steel may require a pressure of 2500 lbs. per square inch, while for a hard steel, at the lowest forging temperature, a pressure of about 14,000 lbs. becomes necessary. Taking also into account the different cross-sections of forgings, the working pressure of a forging press may vary in the proportion of one to ten, and even more.

When the press was first introduced on a large scale for forging heavy steel ingots, about twelve years ago, the double-acting steam-pump was considered to be the most economical apparatus for producing high pressure, and the accumulator was so arranged as to allow two or three degrees of pressure to be exerted; for instance, 2800, 4200, 5600 lbs. per square inch. This involves a very large initial outlay on the plant, and the economy which theoretically should be realised can only be effected if the attendant is always on the watch to adjust the pressure exactly to suit the resistance; as a rule, however, he seldom takes the trouble, and the machine works most of the time at the full pressure. Against the intensifier it was always urged that the consumption of steam was much greater than with the steam-pump, on account of the whole space beneath the piston being filled at each stroke with steam at the full boiler pressure, while the resistance to be overcome varied greatly.

The fact, already alluded to, that the piston always immediately stops when steam is cut off, clearly proves that the expansive power of the steam in the cylinder always exactly

PLATE IV.

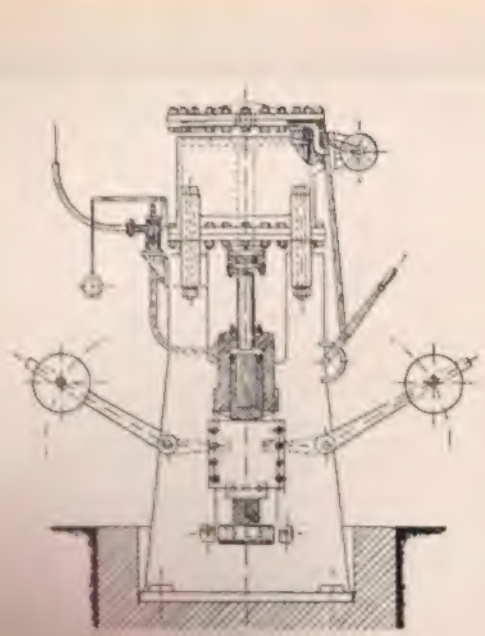


FIG. 1.

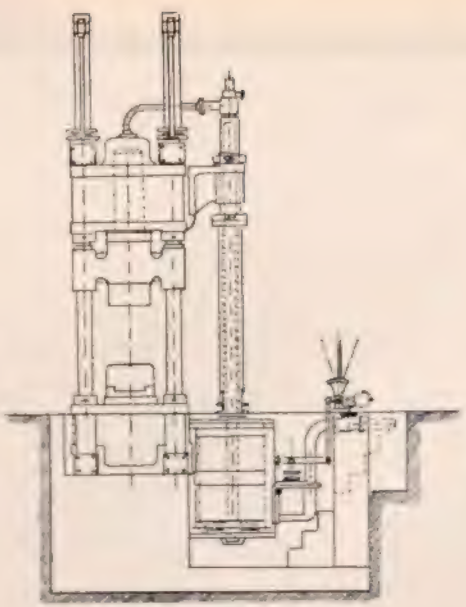


FIG. 6.

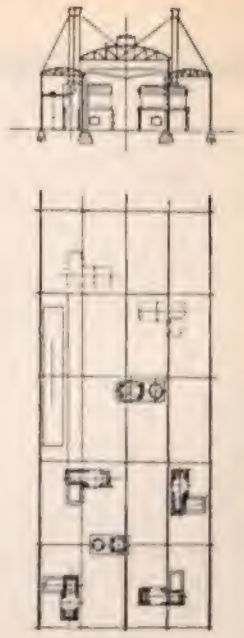


FIG. 7.

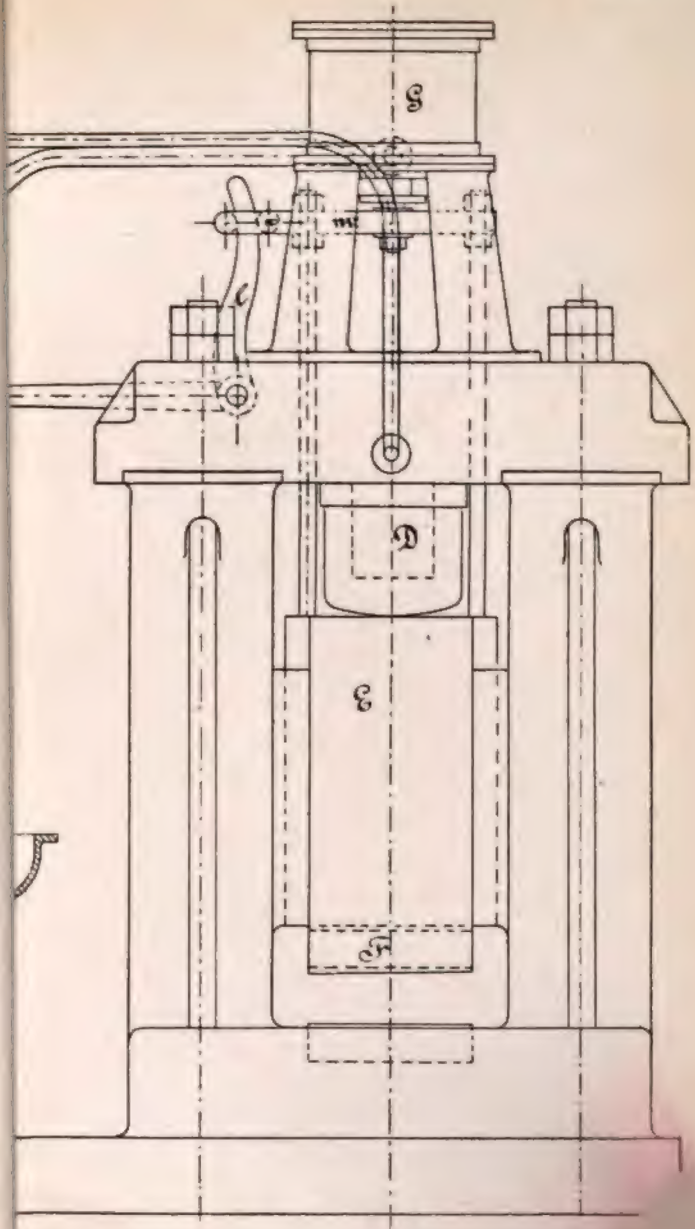


FIG. 2.

PLATE V.

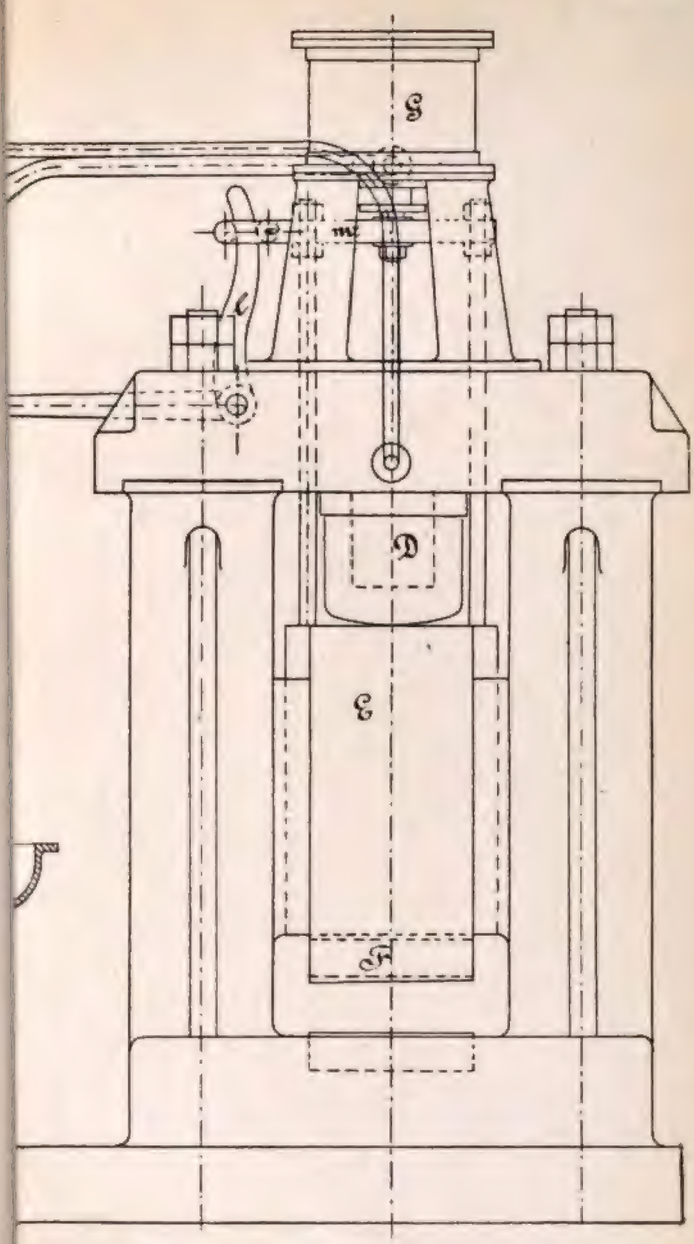
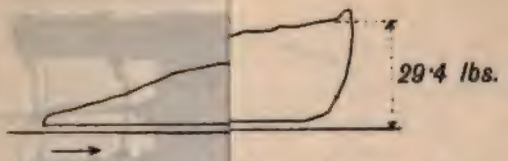


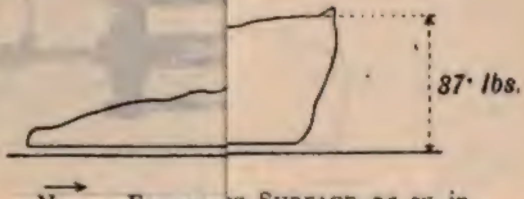
FIG. 2.

PLATE VI.



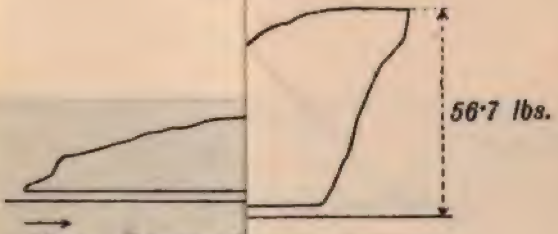
No. 1.—Forging S Surface, 72 sq. in.

Very Brown.



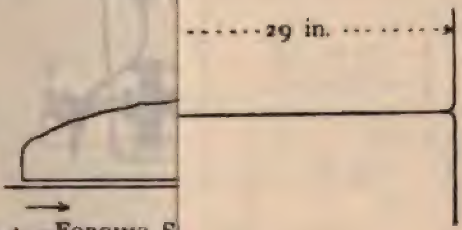
No. 2.—Forging IG Surface, 75 sq. in.

Dar rly black.



No. 3.—Forging S Surface, 348 sq. in.

Re ed red hot.



No. 4.—Forging S

Dark

Ballantyne, Hanson & Co. Edinburgh & London.

PLATE VII.

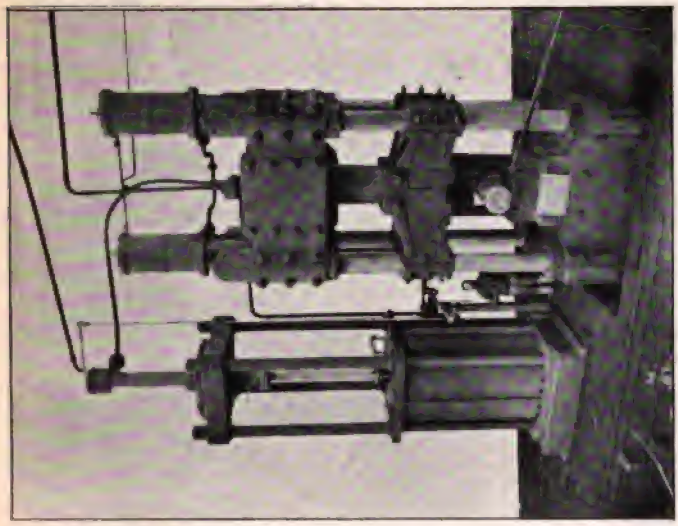


FIG. 5.

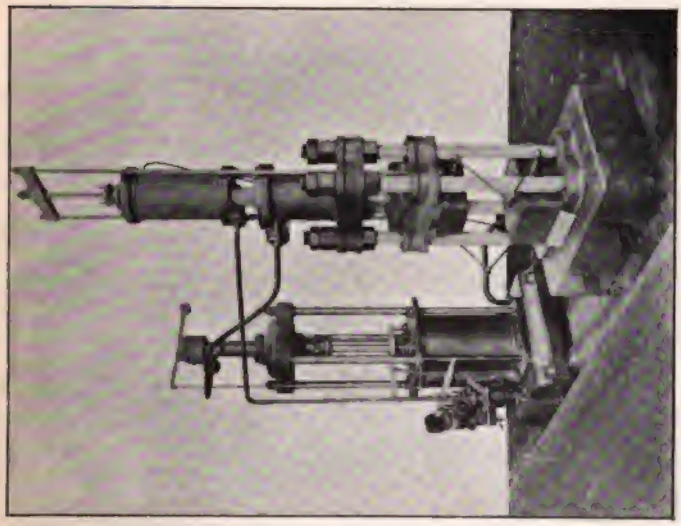


FIG. 4.

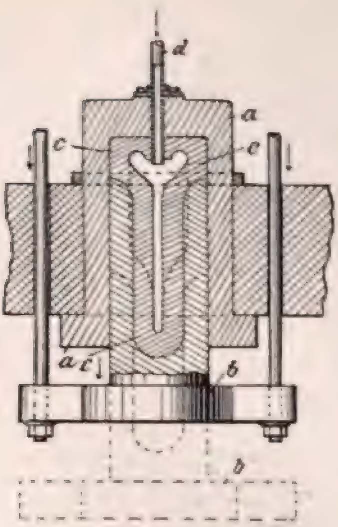


FIG. 8.

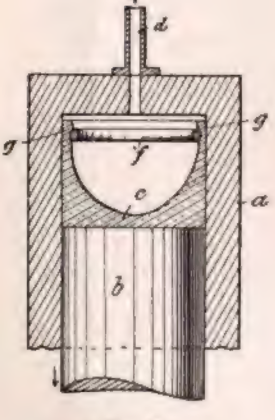


FIG. 9.

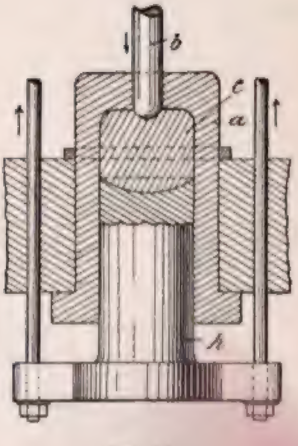


FIG. 10.

corresponds to the resistance which the piston has to overcome, but in order to obtain absolute certainty on this point it was decided to make a test with an indicator. For this purpose the indicator was fixed to a 1500 ton forging press in such a manner that the cylinder of the instrument could be placed in direct communication with the under part of the intensifier cylinder, while the indicator card was driven off the piston rod by means of a friction roller. A very small ingot was purposely placed under the press, and the diagrams were obtained which are shown in Fig. 3, Plate VI. These show that at first a steam pressure of only 21·6 lbs. per square inch was necessary, and that it rose gradually to 28 lbs. The full boiler pressure was only required when the ingot came to lie with its whole length upon the anvil (see No. 8), covering the latter entirely. This shows clearly that the intensifier is the most economical appliance for putting an extremely high pressure on water. In fact, it cannot be otherwise, since any surplus pressure under the piston accelerates the latter, causing expansion to take place in the cylinder, and thereby reducing the steam pressure, while the further entrance of steam is checked by the piston valve for distributing the steam which is under the control of the attendant. It should be particularly noted that the lifting and lowering of the ram of the press is effected by low-pressure water, so that the press cylinder always remains filled up with water, and the high pressure is only brought to bear the moment the head touches the piece to be forged.

The doubt was also formerly expressed, whether the speed of press ram under these circumstances would be sufficient for forging; but this fear, too, is entirely without foundation, since the largest presses are capable of delivering 20 full strokes per minute, which means a speed of 10 feet 6 inches per minute. As regards light strokes for finishing the surface of a forging, it is possible to make 40 to 70 per minute. Such great diversity is shown in the application of the hydraulic principle to the forging press, that it may be of interest to discuss some of the more prominent types, both of those actually built and of some which are not yet complete, but in all cases the employment of the intensifier is shown to be most advantageous. One of the smallest examples at work is used for squeezing puddled blooms,

working at from 150 to 250 tons (Fig. 4, Plate VII.). With regard to this, it was at first generally thought that the press could not satisfactorily replace the steam-hammer, but experience has proved the contrary, namely, that the pressed blooms show less waste and a better quality of iron than those forged under the hammer. As a result of these, eight presses have been built and put to work in the last few years. The next size is a press of 500 tons, which is used to forge rings, of which tyres are made, waggon-axles, &c. Then follows one of 800 tons, which is already powerful enough to forge slabs of about 36 inches square; the sizes then increase to 1200 tons, 1500 tons, 2000 tons, and so on, up to 15,000 tons (Fig. 5, Plate VII.).

In designing different forging press installations, it was found that great inconvenience resulted from having the intensifier connected to the press cylinder by means of piping. The operations of the crane were interfered with, and more than this, the vibration which must occur in forging presses caused the pipe to leak at the joints. The steam-cylinder was, therefore, at the author's suggestion, placed below in the foundation, and the small hydraulic cylinder was fixed on the cylinder of the press. This arrangement gives a press free from obstacles on all sides, and the vibration does not affect the pipe connections (Fig. 6, Plate IV.). In such cases where the local conditions do not permit of placing the steam-cylinder underground, an arrangement of the intensifier is adopted, with the hydraulic cylinder placed on the ground. This allows the water under pressure to be led through the hollow columns, so that the effect of the vibration is obviated.

A further advantage of these arrangements is that the building for such an installation is much cheaper than for presses with steam or water cylinders placed above, by reason of its being 10 or 15 feet lower, and also shorter, because the furnaces can be built on both sides (Fig. 7, Plate IV.). Attention is particularly directed to the heating furnaces with the boilers placed on the top. These furnaces have, for a long time past, given very good results, and have recently been adopted for several new press forges, on account of their cheap construction and economy. The furnaces are so constructed as to allow the short ingots to be laid crosswise to the length of the building, while the long ingots are placed parallel with the length of the building, thus

utilising all available space, and allowing plenty of room for the work of forging; the traverse of the crane between the furnaces and press is also much shortened.

For the first heating up of large ingots the annealing furnace is employed, since the furnaces situated within the range of the forge crane cannot well be used for this purpose, on account of having to keep the forging press going to its utmost capacity. The annealing furnace is specially provided with its own crane, and is similar in design to a coal-fired soaking pit. It can be of any length, and by having several fire-grates arranged along the side it can be wholly or partially heated as required.

The arrangement shown in Fig. 6, Plate IV., illustrates the manner in which several rams and cylinders may be applied to a big forging press without increasing the weight or cost of construction.

Low-pressure water can be used, equally as well as steam, for actuating the intensifier. The question of finding a more suitable material for packing still demands attention, and no effort is being spared to find a satisfactory substitute for the leather rings, which cause much wear in the cylinders and rams. The experiment of putting a metal ring round the leather packing has been tried, but without complete success, owing to the impossibility of lubricating surfaces which are exposed to such excessively high pressure. One idea which has suggested itself to the author is to dispense with the leather packing, and to place inside the cylinder an india-rubber envelope or bag, into which the water under pressure would flow. There would be no more friction of moving parts, but only a peeling off of the india-rubber from the walls of the cylinder. Figs. Nos. 8, 9, and 10 (Plate VIII.) show various ways in which this might possibly be carried out, and experiments are now in progress, the results of which will be communicated later.

DISCUSSION.

Mr. A. T. TANNETT-WALKER, Member of Council, said that he disagreed with the author in his statement that, on account of the advance of electricity as a direct acting power for driving auxiliary machines, the employment of hydraulic pressure was being rapidly abandoned. If Mr. Daelen would call upon Mr. Ellington, or any one connected with the London Hydraulic Power Co., he would find something like a hundred miles of mains and millions of gallons of water, at a pressure of fifty atmospheres per square inch, were being delivered every day, and at less cost than was possible by any other power. By experiment it had been found that its cost was only a little over 4d. per 1000 gallons. Therefore there was no fear of hydraulics going to the wall, although electricity was making rapid strides. Mr. Daelen had brought before the Institute the intensifier in connection with the Breuer-Schumacher press, with which his name had been very prominently associated, and he stated that he had himself successfully solved the problem of doing away with pumps by the introduction of multiplicators, but he did not lay claim to being the inventor. As a matter of fact, the intensifier had been first set to work in connection with a hydraulic press by the late Benjamin Walker, his father, in the works of Tannett, Walker, & Co. in 1869. He had a tracing of the intensifier designed in the year 1866 by Mr. Benjamin Walker, but he was quite ready to admit that Mr. Daelen might have introduced some improvements. The author had not given them any idea as to how the valve was made, and that was the life and soul and the lungs of the whole business; nor had he given information as to how he was able to make the press work up and down so as to get the number of strokes mentioned—seventy per minute. In spite of what Mr. Daelen had said, he was still absolutely against the intensifier, which was really a flywheel-less pump. He was still of opinion that the compound or triple expansion engine, with condensation, was more economical, whatever pressure was required, than was the intensifier which Mr. Daelen had described. He could not imagine how the author by means of

a simple cylinder hand-worked, it would seem, could produce the requisite volume of pressure water and consequent horse-power.

Mr. ERNEST F. LANGE (Manchester) said that the last remaining advocates of the steam-hammer had for the past five years given way and admitted that for forging work there was nothing so economical as was the hydraulic press, yet those who had had experience of steam-hammers would admit that at certain times they did very economical work. When the hammer was once warm to its work and operated by an expert forge-man, one could observe, by the way in which he was doing his work, and also by tests, that for a portion of its time the steam-hammer was working very economically. One could get excellent diagrams and work results to show that. Yet every one knew that the steam-hammer, taken on the whole, was wasteful in steam. There was the one question alone of condensation in the large cylinders, and all those who had to do with steam-hammers knew what a great loss that represented, and the same arguments would apply to the steam-driven intensifier, which could be compared to the cylinder of a steam-hammer. He had tried hard to understand on what ground Mr. Daelen claimed it to be absolutely proved that his method of producing high pressure was the cheapest. But many members would require a great deal more than the results of an indicator trial before they would agree with the large claim which had been made for the press with regard to economy in working.

Sir EDWARD HAMER CARBUTT, Bart., Member of Council, said he had not intended to intervene in the discussion, but as the question of how long ago it was since the machine was invented had arisen, he would like to say that forty-five years ago the application of a big steam-cylinder working a small hydraulic ram was used for a foundry lift in Derby. He was serving his time in the Midland Railway shops at that time, and that big steam-cylinder with the small hydraulic ram was put up to work in the foundry lift. It would be seen that it was a long time ago. In reference to what Mr. Tannett-Walker had said, Sir Joseph Whitworth's attention had been directed to the hydraulic

press, because having at work a steam-hammer in the middle of the big city of Manchester, its vibration interfered with the instruction of the school children quite close to his works, and although he went to a large expense to isolate the steam-hammer, he could not succeed in stopping the noise. In the end he set to work to make the press which was afterwards connected with his name. Sir Joseph Whitworth and the late Mr. Benjamin Walker had done a great deal to perfect the press which was at work in this country and in several other works abroad. He could not help feeling that Mr. Tannett-Walker might be right that there would be some difficulty for one steam-cylinder and one ram to get up suddenly the pressure requisite for 5000 or 6000 tons. Of course, if one had several of those intensifiers and several boilers, it might be done, but it would be done at greater expenditure of steam. He agreed with Mr. Tannett-Walker that if he were going to put a plant down, he should put a pumping-engine which could be working when the machine was not at work, and gradually accumulating water pressure into the accumulator. He thought that that would be cheaper than the proposal of Mr. Daelen. The members were all very much obliged to Mr. Daelen for bringing his paper before them, because it was very interesting to find how other minds worked. They might find reason to alter their views, but at present he should back up the experience of Mr. Tannett-Walker, which was so great, in reference to the ordinary press with pumps being preferable to Mr. Daelen's proposal.

Mr. SAMUEL LLOYD said that as to the question when the plan was first adopted, he might mention that when a partner in ironworks at Wednesbury he took out a patent for cutting up large pieces of steel and iron by hydraulic pressure, because their ordinary shears were apt to get broken; but he found Mr. Charles May, a member of the Institution of Civil Engineers, had taken out a patent before him. Mr. Eastwood also took out a patent, and joined him (Mr. Lloyd). Going back to the time of Mr. Charles May's patent was going back to about 1850, so that it was very ancient history to trace the first inventor of the thing.

Mr. Tannett-Walker said they could go back to Bramah for the invention of the intensifier, but it was the application and the mode of doing it which were in question.

Mr. R. M. Daelen, in reply, said that Mr. Tannett-Walker had spoken about the low-pressure water. He thought it was well known that for cranes and auxiliary machines in rolling-mills and steelworks it is not convenient to have two powers—electricity and hydraulic power. As in most cases at the present time electricity is applied in those establishments, it is preferable to have only this power for auxiliary purposes, and therefore in many cases low-pressure water was abandoned. As regards the invention of the steam intensifier touched on by Mr. Tannett-Walker and Mr. Lloyd, he had already stated in his paper that he did not claim to be the inventor. However, he thought that Messrs. Breuer and Schumacher and himself were the people who introduced the intensifier into practice. It very often happened that there was a good idea proposed which was not taken up, and was not introduced into practice, because at first it was not successfully executed. They had introduced it on a large scale, and the best proof was that Messrs. Breuer, Schumacher, & Co. had executed up to the present time 270 different presses.

Continuing, he said that Mr. Tannett-Walker was doubtful even if the effect could be obtained by the intensifier for a very big press. He could say that it had already been successfully applied to forging presses up to 10,000 tons. There was one working in St. Petersburg and another working at Dillingen in Prussia, and they both worked very well. There was nothing to hinder its application for a larger press up to 15,000 or 20,000 tons, though it would be necessary then to use several intensifiers for one press. He had to remark that the pressure was only given at the moment that the head touched the ingot, and then the quantity of high-pressure water needed only to be calculated for a single stroke of the intensifier ram, which was in the case of small forging presses about 4 inches, and for very big presses up to 8 or 10 inches. The pressure of steam should be as high as possible, so as not to have too large a steam-cylinder. Then there was no difficulty in that respect. As to

the number of strokes, that large intensifier did not go up to 70 strokes for the whole time, but only for very small strokes.

What he had stated with regard to packing was only a proposal of his, but he did not doubt that it would be successful. He had only tried it on a small scale as yet, but on a future occasion he hoped to be able to refer to some success. With regard to what Mr. Tannett-Walker had said as to the piston-rod, that never occurred in connection with the small cylinder. They always took care to have the piston-rod long enough so that the hot part did not go into the water, and therefore they had not much trouble with the packing. In respect to what Mr. Lange had said in comparing the steam-hammer with the press, he thought that it was a well-known fact that the press possessed more than double the effect of the steam-hammer. There might be some cases where the steam-hammer would do good work, but in the case of forging very heavy ingots the steam-hammer had been abandoned altogether. As to the diagrams, their object was not to compare the effect of the steam-hammer with the press. They were only prepared to show that the pressure of the steam under the piston of the intensifier was always in proportion to the resistance which the ram of the press had to overcome when forging the ingot. That was the only purpose for which he had prepared those diagrams. He had referred generally to the capacity of the intensifier, and not especially to that of forging presses. Sir Edward Carbutt had stated that he doubted whether the intensifier worked as economically as a steam-pump. He thought that was clearly proved by the diagrams. A steam-pump generally required an accumulator, or it must be directly connected with the big cylinder of the press. There were, however, several valves between the pump and the cylinder, which are the principal reasons for its being untried. The quantity of high-pressure water was not in proportion to the amount, because as soon as there was a little wear the water went back into the pumping cylinder. In using the steam intensifier all the water produced by the steam must also go into the high-pressure cylinder, and as distribution valves were fitted to the steam-cylinder only, and not to the ram cylinder, there was no source of waste. It was a well-known fact that a steam distributing apparatus could very well be maintained tight, giving no loss,

whereas a distribution apparatus placed in the high-pressure water was always a frequent source of trouble.

The PRESIDENT said he was sure they all felt they owed a vote of thanks to Mr. Daelen for his interesting paper, and for the clear exposition of his views upon the matter.

The vote was carried by acclamation, and the following paper was read:—

THE ECONOMICAL SIGNIFICANCE OF HIGH SILICON IN PIG IRON FOR THE ACID STEEL PROCESSES.

By AXEL SAHLIN, Millom, Cumberland.

We read and hear continually in this year 1901 about American competition and its dangers to the British iron industry. The English papers bewail the superior natural resources of the United States, the lack of technical education at home, the tyranny of the labour unions, and a number of other disqualifications under which the British industry is suffering, or supposed to suffer. Having spent the best part of my active life as an iron and steel works engineer in the United States during the period of revolutionary growth of the iron industry in that country, and the balance in England and on the Continent, I feel prompted to call attention to a prevailing local requirement, which is doing much to hamper progress in a certain branch of the British iron industry. I refer to the demand of high silicon in pig iron for the acid steel processes.

Being connected with one of the larger, if not the largest, independent producers of hæmatite iron, or—as the Americans would describe them—"merchant furnaces," I have investigated our sales books for the last two years, and find that the majority of our customers, many of them Siemens open-hearth steelmakers, specify over 2 per cent. of silicon in the iron they buy from us, while a few insist on not less than 2·5 per cent.

Iron of this composition is never intentionally produced for the American steelworks, and the large and effective American furnaces, about which we read and hear so much, could not economically produce it, if it were wanted. Just as little could some of the old-fashioned British furnaces, with their weak blast and small hearth, running on siliceous mixtures of native or Spanish hæmatites, produce the iron which our American competitors are so successfully turning into steel.

It would be interesting to learn the reason for this preference for high silicon pig iron amongst many of those steelmakers

who procure their iron by purchase in the open market. I have now before me letters from some firms, who state that their quality suffers if the silicon in the iron is lowered. Others, with whom I have discussed the matter, assure me that they have no objection to iron lower in silicon; but when the next order from these same firms reaches us, it still contains the limitation—"silicon from 2·25 to 2·75 per cent."

Many old-fashioned furnaces make iron as required without effort, and would, in fact, find it difficult to reduce the silicon without at the same time running up the sulphur. Therefore, the steelmakers have perhaps never fully realised what the "2·5 silicon" signifies to the blast-furnace operator; nor have they realised how their demand is crippling progress in iron-making on American lines.

Experience teaches us that iron will be higher in silicon:—

(1) As the fuel is increased.
(2) As the size of the hearth is reduced.
(3) As siliceous ores are employed—that is, ores which require large additions of basic flux.

These same conditions also contribute effectively to retard the working and reduce the output of the blast-furnace.

A year ago it was decided by the Directors of the Company with which I am identified to construct a new blast-furnace on the north-west coast. I was fairly familiar with the art as practised in America, but the question which had to be settled was, how far were American conditions applicable on the north-west coast of England? It was found that the materials which we had to employ were better than those used in a great number of the American furnaces. The ores were lumpy and generally fairly dry; they contained sufficient fluxing constituents, and yielded a mixture varying from 51 to 55 per cent. of iron. The coke was, as long as exorbitant prices did not make the coke people careless, as good as, or better than, the average American coke. The limestone was pure and uniform. All conditions seemed to be there to warrant the building of a large and effective furnace such as those used in America, until I submitted to our sales department the question of silicon.

To get out a large output, say from 400 to 450 tons per d

a hearth diameter of 14 feet would be required. This would, I felt certain, bring the silicon in the iron down to about 1·50 to 1·20. Would they be willing to market this iron? I was met with an energetic No! and referred to the above-mentioned specifications in our sales books. My suggestion that the steelmakers might be reasoned with on this point was met with the information, that as high silicon often was specified, and as our competitors were ready and willing always to furnish it (they could, perhaps, not help doing so with such plants as they had), we were compelled to do the same.

Good-bye, therefore, to all dreams of a fully effective blast-furnace and of a modern output. We were restricted to a compromise, only to make a weak attempt to approach what was being done in the United States.

To learn how far we dared go in reaching for capacity, I made a special trip to America, went over the old familiar ground and consulted good friends, some of whom I found grumbling because they could not turn out 500 tons of iron per day per furnace. I described to them our raw material, and got the encouraging verdict, "You ought to do well!" but when I mentioned the 2·5 per cent. of silicon, their expressions changed. The first question came: "What do you want it for?" To which my only rejoinder was: "Our customers specify it." Next came the advice: "Don't you make your hearth too large, or you won't make that iron." The result of careful canvassing and investigation was the establishment of the necessity to reduce the hearth diameter to 11 feet; and on an 11 feet hearth no great product can be expected.

I also found that, all over the Continent of America, no such iron as we in England are forced to sell as Bessemer iron was regularly made. The nearest approach to it is the No. 1 foundry iron mostly produced by the Southern furnaces. While, therefore, the American furnaces producing steel iron reach outputs of 400, 500, 600, or even, occasionally, 700 tons per day, there is to-day no furnace in the world worked to put 2½ per cent. silicon into the iron that reaches an average output of 250 tons per day, and only few that top 200 tons.

It must be admitted that, with American steel made from low silicon iron pouring into markets which Great Britain so long has

called here, this restriction imposed on the ironmaker is anything but encouraging.

But not content with reducing the output, which sends up cost of labour, repairs, interest, and general expense, the high silicon can only be obtained by a sacrifice of fuel. Practically, I have found that, with such materials and such furnaces as we now employ on the north-west coast, the raising of silicon from an average of 1·75 to 2·25 calls for an increased coke consumption of about 4 per cent. Besides, certain ores, rich in bases, have to be used only in carefully limited quantities. The siliceous ores, which are preferable for this class of iron, require flux, and more limestone is the consequence.

Sacrifice of output, coke and limestone, and limitation in the selection of ore, is, therefore, the price which those of the blast-furnace people who stand prepared to go ahead must pay to meet the requirements of a considerable part of their customers.

So far from the standpoint of the would-be progressive iron manufacturer.

Now, to take the side of the steelmaker, the writer of these specifications. Does he derive any commensurate benefit by insisting on them? Is he not rather standing in his own light? And as to the increased cost of the iron, who is to pay for it? In some cases, it is true, the hard pushed blast-furnace owner, who may stand ready to give up even the last penny of profit rather than face a shut-down and disorganisation; more often the steelmaker himself and his customers. But in either case, in the last instance, the British industry and the country at large.

In trying further to answer this question, it will be necessary to consider separately the Bessemer and the open-hearth processes.

In the Bessemer process, we know that almost the whole of the heat required for the conversion must come from the combustion of silicon contained in the iron. The greater the excess of silicon, the hotter the charge, the longer the blow (that is, the slower the process), the greater the loss, the more expensive the repairs and maintenance of plant, and, above a certain point, the poorer the quality. On the other hand, too low silicon stands for cold heats, heavy skulls, and generally bad working. G modern American practice to-day is to run the silicon in the

at from 1·30 to 1·20 per cent. I have, however, frequently seen heats successfully blown with less than 1 per cent., and even as little as 0·80 per cent. of silicon. So low a percentage I do not, however, advocate. With silicon at 1·20 in the bath, with a sufficient tuyere area, a wide converter bottom, ample blast pressure, and rapid working, the time of a blow should not exceed 11 to 13 minutes, and a fair percentage of scrap can generally be charged into the converter. The linings and bottoms should stand well, and the output should be at about the most satisfactory point. When remelting the metal, allowance must, of course, be made for oxidation of silicon in the cupola, but even under these circumstances 1·5 to 1·4 silicon should give sufficient heat for a well-conducted process.

If a plant is working so slowly and disjointedly as to require more heat, it is extravagant, uneconomical, and out of date, and should, as soon as practicable, be given a rest.

Again, in the Siemens furnace, silicon is a costly fuel. Here the producer-gas can be used more economically for raising the temperature of the bath, and if this in any special instance is found impracticable, it is almost certain that the regenerators, the draught, or the arrangement of the furnace are at fault. It is not easy to build a furnace with too large regenerators. In most furnaces designed a generation ago they will be found insufficient. But to rebuild a Siemens furnace so as better to utilise the heating power of the gas is, however, a comparatively small matter. In the United States open-hearth steel makers prefer the silicon in the iron kept as low as is possible without extravagance, and without incurring the risk of an increase of sulphur. They maintain that a short desiliconising period, while in many cases reducing the duration of the heat, in no way influences the quality of the product. To obtain a jacket of slag, it is certainly better economy to add flux than to oxidise such out of the iron. High silicon in iron for the open-hearth furnace is, therefore, held to increase loss and cost, without in any way improving the product.

The reference to the above-mentioned sales books and specifications shows that this opinion does not prevail amongst some British steel-melters. Why this is so I have not been able to learn.

It may be rather late in the day to make this plea for low silicon iron. When an ironmaster converts his own iron into open-hearth steel, and has at his disposal a blast-furnace plant sufficiently powerful and efficient to produce a low sulphur low silicon iron, he will, undoubtedly, without solicitation, adjust his views regarding silicon to suit his pocket-book. And as for the struggling, independent blast-furnace marketing a product of Bessemer iron often through the agency of brokers, and the equally crippled maker of standard grade steel, who looks to the same intermediary and to the warrant-yards for his raw material, I venture the prediction that many of these will soon be driven to the wall, unless they sensibly combine forces, each plant becoming a co-operating link in the unbroken chain of processes which turn the ore into merchantable steel. Andrew Carnegie has recently been quoted as having said: "Henceforth there can be only one profit made from ore to finished article." He is unquestionably right, and unless British manufacturers heed his timely warning by, as far as possible, adapting their plants and views to meet each others' requirements for combined economical production, the British iron industry will find the coming struggle for position and markets more unequal than it otherwise need be.

DISCUSSION.

The PRESIDENT said they were all much obliged to Mr. Sahlin for his paper, which from many points of view was interesting and informing.

Professor ARNOLD said that he had listened to the paper with considerable interest, because one of the most experienced and reliable Bessemer steel makers in Sheffield had recently quoted to him the American practice in that respect. He had been assured that the carbonisation of the blown heat was made by a comparatively small quantity of pig iron from the next cupola tapped, and that the consequence was that in the rapid working the axles made from the steel were so oxygenated that when worked out they were extremely "roaky"—so much so that no British railway inspector would have accepted them. His deliberate opinion was that the British practice, although costly and uneconomical, gave a much better quality of steel than did the American practice.

Mr. JAMES RILEY, Vice-President, in criticising, said that British iron and steel masters had been lectured very much for their sins by their friends across the water, but they did not want to be punished for sins which they had not committed. He had told Mr. Sahlin that morning that he could not understand what people he had met with. To charge the open-hearth steel makers of Great Britain with asking him or any one else (except for special purposes) to give them iron rich in silicon was an unheard-of charge. For twenty years of his life one of his troubles had been to get possession of pig iron sufficiently low in silicon. When he first went to Scotland and commenced the mild steel business, he had to fix what the character of the iron should be, and yielding to pressure with regard to what the ironmakers could do, or would undertake to do, he was compelled to put the maximum limit up to 2½ per cent. of silicon. That had remained the maximum limit for a long time, but with a great deal of trouble with the

makers in order to keep it under that maximum. About ten years ago, during the last "boom," and when the power was in the hands of the ironmakers, the steel-makers had to be very humble, and it was then, at the request of the ironmakers, that the maximum limit was raised to 3 per cent. There was one firm with whom they did business whose iron was always lower in silicon than this, and that firm commanded a better price for the metal than did others. He thought that the author had been influenced by the desires of the makers of Bessemer steel, or else that he had come into contact with gentlemen who made special qualities. But surely one did not legislate for exceptions like that. If any one wanted to supply the exceptional demand, let them provide facilities for doing so, but they should not make the majority of manufacturers suffer on behalf of the exceptions. When he read the paper, he wondered whether during the last few years any change had come over the desires of the open-hearth steel makers, so surprised was he at the charge brought against them.

Mr. ENOCH JAMES remarked that he could confirm what Mr. Sahlin had said in some respects. He had been in a firm where they had to make the pig iron and convert it into steel, and in less than two months the output of that Bessemer shop was increased by 25 per cent. above what it had been before they began paying attention to the quality of the pig iron. More blast was put into the blast-furnaces, the output was increased, and the percentage of silicon reduced in consequence, time in solution having great influence upon the content of silicon. With such pig iron the blows in the Bessemer shop were considerably shortened, and the make of steel greatly increased. In dealing with the question of the quality of pig iron, more reliance was placed upon the length of the blows than upon the chemist's reports of two or three samples only. He thought this confirmed in a very practical way what Mr. Sahlin said. He might say he knew of some instances where buyers of pig iron asked for high silicons because they were makers themselves, and generally had plenty of low silicon iron on [illegible] which they desired to clear. Silicon was most costly to [illegible] into the pig iron and expensive to take out, and the success

Bessemer shop depended very largely upon the quality of the iron with which it was supplied.

Mr. JOSEPH COOPER (Jarrow) wished to say one or two words from a blast-furnace manager's point of view. He felt they ought to welcome Mr. Sahlin as coming amongst them from a country where such excellent results were obtained from blast-furnaces. For a good many years past several works in this country had been trying to vie with the Americans in production, and one or two companies had spent a considerable amount of money with that object, but unfortunately with not very great success. The works with which he himself was connected, some ten years ago had spent a considerable sum of money in building a blast-furnace, stoves, compound condensing engines of large size, boilers, and everything else necessary for the furnace to work alone. He was sorry to say that the results did not meet with the expectations of the directors of the Company. He thought some managers in this country had come to some kind of conclusion as to the cause why they could not make the productions which were made in America. One reason was the very varying analysis of the ores which were imported here, and another the very low iron yield of the ores that were obtained. They found on the East Coast that the Bilbao ores which they most depended upon ranged from 8 per cent. to 15 per cent. in silica. Sometimes cargoes would immediately follow one another, one with 8 per cent. of silica and another with 15 per cent. Under such conditions it was a difficult matter to get the results one hoped to obtain. It would be interesting to know if Mr. Sahlin was successful in producing 500 tons from one blast-furnace in one day at his works on the West Coast. He was rather afraid that the author would have some difficulty in doing that, especially with such ores as those he had referred to. He understood the author said that if he could not get iron accepted with less than 2½ per cent. silicon, he was rather afraid he would not get the results he hoped to get. Perhaps the author would correct him if he was wrong in stating that. He might say further that the blast-furnace owners in this country were very conservative, and had a very great objection to spending money unless they saw

some one else had done so, and proved new methods of doing work to be successful. The Company with which he was identified had been one which had gone very far in the direction of adopting mechanical means for replacing hand labour with success. He believed his firm was the only one in Great Britain where for a considerable period they had cast their iron in a casting machine. That had been going on now for thirteen months without intermission. Every day's make of their hæmatite furnaces had been poured through the machine, and although there had been several break-downs, the machine was repaired in time to prevent a stoppage of the work. In addition to that, as he had previously remarked, a considerable amount of money had been spent in making what had been called an American furnace, which he had previously described, which had not proved very satisfactory so far. Further, the Palmers' Company sent the whole of their molten slag and hæmatite pig iron away from the furnaces in a molten state in ladles—that was with regard to hæmatite. In the Cleveland furnace the whole of their slag went away in a molten state, including the roughing slag. He believed they were unique in that particular. The directors of the Palmers' Company were to be credited with having shown a go-ahead spirit, and with adopting means for doing work by machinery which formerly was done by hand-labour.

Mr. F. W. Harbord said there was one point he should like to ask a question upon, with reference to the reduction of the silicon by increasing the size of the hearth. It seemed to him there was a great demand in this country for a low silicon pig provided the sulphur was low; in fact, the great difficulty in this country had been to get pig low in silicon and low in sulphur. He thought that all the open-hearth people would be only too glad to get such pig iron. He knew when he was connected with the works that they wanted to get some iron suitable for working in the basic Siemens process which was low in silicon, but they could not get it both low in silicon and low in sulphur. As soon as they got low silicon the sulphur went up. If in America, simply by increasing the size of their hearths and increasing their pressure of blast, they were able to get both low sulphur and low silicon, it was a most vital

for the ironmasters of this country to consider if they could not do the same. Even in Bessemer practice they could do with very much less than 2½ per cent. provided the sulphur was also low. There were two reasons why they wanted reasonably high silicon in the Bessemer: one was that the existing plants were not adapted for the rapid work which was the chief feature of American practice, and therefore they wanted more silicon to keep up the heat of the blow; and the second was that they must keep their sulphur low. Instead, however, of having 2½ per cent., he thought that they could at least manage with 1¾, or even 1½ in many plants, provided the sulphur was low. If their American friends could show them how to make pig iron low both in sulphur and silicon from their present raw materials, they would render a great service to the iron and steel industry of this country.

Mr. R. A. HADFIELD, Member of Council, fully confirmed the points referred to by Mr. Harbord as to the desirability of pig iron makers being able to supply material with lower silicon, that is, under 1½ per cent.; also that this material should not contain more than about 0·03 per cent. of sulphur and phosphorus, though low silicon iron is usually accompanied with high sulphur. He would also ask Mr. Sahlin whether he could give a pig iron containing not more than 0·8 per cent. silicon with sulphur and phosphorus not exceeding 0·04 per cent.? Such a material could be obtained now, but it contained a comparatively high percentage of manganese, which was objectionable for special purposes.

Mr. J. E. STEAD, Member of Council, asked the author whether he had any exact data proving that, with ore of identical composition, and coke and other things the same, the change from a small hearth to a large hearth, and from a low-pressure blast to a high-pressure blast, did actually reduce the silicon in that way? Generally speaking, blast-furnace managers, in this country at least, considered that the silicon contained in the pig iron depended mainly on the amount of silica in the ore. What they were at present fighting against in this country was the high silica in the pure ores, which was gradually getting higher

and higher. The Bessemer pig iron manufacturers were not anxious to make high silicon (2·5 to 3 per cent.) pig, excepting for the Bessemer process; they would prefer to make lower silicon pig for open-hearth steel-making. He spoke for the East Coast. Mr. Sahlin came from the West Coast, but he thought the same conditions prevailed there. It was difficult to keep silicon down as low as desirable in Cleveland forge and foundry iron, and many siliceous ironstones could not be worked on account of this difficulty. Penalties were imposed on merchants who imported ores higher in silica than the normal.

The Right Honourable Sir Bernhard Samuelson, Bart., Past-President, said he was not able to say what would be the result with identical materials in reference to hæmatite, but with regard to Cleveland he had lately had some experience which might be of interest to the Institute. The materials remained identical both with regard to the ironstone and the quality of coke, and by increasing the output of No. 4 furnace at Newport from about 750 tons to over 1000 tons, the reduction of percentage of the silicon in the pig had been upwards of 20 per cent. Where they had, when blowing slack-blast, something like 3½ per cent. of silicon, it was reduced to under 2½ per cent. when they increased the output of the furnace by 30 per cent. Whether the result would be the same in hæmatite it would be difficult to ascertain on the East Coast, for the reason which had been stated, namely, that the ores received from Spain varied constantly in their constituents. The pig they were making was No. 3.

Mr. Greville Jones said that with the same Cleveland ironstone, making about 700 tons a week, their silicon would range from 2½ per cent. to 3 per cent., but since the furnaces had been driven harder, and were now working nearly 1000 tons a week, the silicon had dropped below 2½ per cent., and was sometimes down to 1¾ per cent. The sulphur was not increased at all.

Mr. F. W. Paul said that, speaking generally, he thought it was correct to say that the difficulty in making regularly good hæmatite pig iron low in silicon was because it dem

rapid driving of the furnace. There was consequently a tendency at times for the furnace to be overdriven. The result was that close hard iron with high sulphur was obtained, when the tuyeres were pulled well back to the full available diameter of the well, instead of being placed some distance into the furnace with a view to reduce the distance between them, causing slower working and consequently increased percentage of silicon. He understood these to be the two conditions relative to the furnace described by Mr. Sahlin in his paper. If the design of the furnace which he had described had enabled him to overcome the risk of making hard iron and high sulphur with hard driving, he would venture to assure him, in speaking for the open-hearth steel makers, that there were many who would even be prepared to pay his company a shilling per ton more for low silicon iron of uniform regular quality. He (Mr. Paul) had read with the utmost astonishment Mr. Sahlin's statement that Siemens acid steel manufacturers objected to low silicon iron, for, judging by his (Mr. Paul's) experience of the last twenty-five years, high silicons had been one of the greatest difficulties he had had to contend with, and had been a source of continual antagonism between blast-furnace pig iron makers and Siemens acid steel makers.

The author dealt with what was presumably the theoretical working of a Siemens furnace in order to prove his contention that a low silicon iron was feasible, and the assumed shortcomings of the steel manufacturers in this country were again prominently brought into view, and they were told that the simple solution of the whole matter was to increase the regenerators, as had been done in America.

It had evidently not occurred to the author that, with the present-sized regenerators which they had in this country, it was necessary at times to vary the respective proportions of pig iron and scrap, with the result that the average percentage of silicon would vary in the initial charge from under 1 per cent. to $2\frac{1}{2}$ per cent., and in the case where, say, 90 per cent. scrap was used, the charge would be worked in very considerably less time, clearly showing that it was not a question of gaining heat by the oxidation of the silicon. It was evident Mr. Sahlin had not even thought of the pig iron used in Siemens basic open-

hearth practice, which contained frequently as low as 3 per cent. of silicon, clearly showing that his theory and deductions were seriously at fault. There should not exist the slightest doubt, after the discussion which had taken place, that Siemens acid steel manufacturers would only be too pleased to avail themselves of good No. 3 iron with not more than 0·05 per cent. sulphur and 1·5 per cent silicon.

Mr. SAHLIN in reply said, he was very much gratified at the full discussion given to his paper. He expected that the criticisms and opposition to his statements from recognised authorities would do much to rectify the reactionary requirement against which he had pleaded in his paper. The statement that the majority of the customers of his company demanded high silicon iron he could not withdraw, however; it was a fact proven by sales books and specifications.

The theory explained by Professor Arnold, that Bessemer steel would become oxygenated on account of short blows—that is, low silicon—he did not think correct; nor was it common practice in the American Bessemer works to recarburise the metal without at the same time deoxidising by means of manganese introduced as spiegel or ferro. He had, however, seen Bessemer steel in England ruined by the reduction of silicon during the blow. This reduction was clearly caused by an excessive blowing temperature, generated by the combustion of large quantities of silicon contained in the metal. He did not think that any one in America nowadays would care to produce steel for railway axles by the acid Bessemer process, but he had a number of years ago examined large numbers of railway axles made from Bessemer steel at an American steelworks using very low silicon in their iron. These axles had since then been satisfactorily used under heavier loads than any British railway axle is exposed to. As to finish, smoothness, uniformity of tempering, and exactness of dimensions, these axles left nothing to be desired.

It had been stated by Mr. Riley that he had always specified iron with a maximum content of 2½ or 3 per cent. of silicon for his open-hearth furnaces. Such iron should not be called low silicon iron. Mr. Riley might have reduced his limit by half and still been on the safe side.

In answer to Mr. Joseph Cooper's statement that his company, a few years ago, had constructed an American furnace, he replied that there was no such thing as an American furnace. The Americans had no monopoly of any special type of furnace, and well-equipped, effective furnaces were being built as well in Germany and Austria as in America. There was nothing in the ores that are imported into Great Britain to prevent a considerable improvement in our blast-furnace work.

In 1895, when he was general superintendent to the Maryland Steel Company, that company started one of their furnaces on a mixture exclusively of Spanish and Mediterranean ores, such as were imported into England. The mixture employed was familiar to the members of the Institute. It contained—

25 per cent. of Mokta,
25 per cent. of Tafna (dust fine),
25 per cent. of Seriphos, and
25 per cent. of roasted Spathic (Bilbao) or Porman.

This burden could be reproduced in Great Britain by any one desirous of trying it. It would carry about 51 per cent. of iron in the mixture and about 12 per cent. silica. It might be of interest to mention that the furnace was fluxed with oyster shells.

A preserved record of one ordinary week's work was as follows:—

Product for the week, 2058 tons.
Average per day, 294 tons.
Coke consumption, 90·5 per cent.
Blast temperature average, 1338 degs. Fah.
Blast pressure average, 14 lbs.
Steam pressure average, 80 lbs.
Total time blast off, 3 hrs. 30 mins.

The furnace was 85 feet high, 18 feet 6 inches in the bosh, and 12 feet 6 inches in the hearth. They could blow up to 18 lbs. pressure. Our North-West Coast ores are, if anything, a little better than those mentioned above, but they would require a higher blast pressure.

He did not expect ever to produce 500 tons per day on the North-West Coast. When he reduced the hearth diameter of the new Askam furnace from 14 feet, as originally planned, to

11 feet, a large output became impossible. If he could reach an average output of 250 tons per day, he would feel proud.

He was glad that Sir Bernhard Samuelson and Mr. Greville Jones corroborated his experience, that rapidity of blowing reduces the silicon in the iron. So would also the size of the hearth, though Mr. Harbord would find that, to reach a large daily furnace production of low sulphur low silicon iron, a great deal more was required than a large hearth and a high blast pressure. A blast-furnace resembled an intricate equation with more variables than there were letters in the alphabet. Change the value of one and all the others are affected. In that he saw one reason why attempts to improve existing British furnace plants so often had proved abortive. In one case, for instance, he was told that the directors of a company authorised the manager to raise the furnace stack, but would not provide new stoves, boilers, or engines, and, of course, the new furnace was a failure, which cost the poor manager his position.

He had been asked by Mr. Hadfield whether he could produce iron with less than 0·8 silicon and less than 0·04 sulphur and phosphorus. It was a pleasure to reply to Mr. Hadfield that he had recently made 350 tons of iron for a special purpose containing less than 0·7 per cent. silicon and less than 0·03 phosphorus and sulphur, the manganese being kept below 0·5. This was being done on an 11-foot hearth.

There was no doubt that the size of the hearth and quantity of blast, as well as the composition of the ores and slag, affected the percentage of silicon in the iron. He was daily employing both of the former agents for governing the working and regulating the output of furnaces; but the question is not one of a couple of pounds of blast pressure per square inch more or less, and he thought that Mr. Stead would agree with him that the condition of the existing blast-furnace plants in this country had not been such as to give the managers a chance of carrying out experiments in this direction. In America the fact was recognised and always taken advantage of.

In answer to Mr. Paul's question why he had decided to reduce the hearth of the furnace which he was building, he would say that this was done wholly to enable him to furnish the sales department with pig iron containing from [illegible]

per cent. silicon, when such was called for. It was done only after serious consideration, and to meet the views of several important customers. He did not know that the diameter of the hearth would greatly affect the coke economy, but the height of the furnace would certainly do so.

On the motion of the PRESIDENT a vote of thanks was passed to Mr. Sahlin for his most interesting paper. The following paper was then read:—

THE PROPERTIES OF STEEL CASTINGS.

BY JOHN OLIVER ARNOLD, PROFESSOR OF METALLURGY IN THE UNIVERSITY COLLEGE OF SHEFFIELD.

PART I.

THE researches embodied in the papers of which this is the first were commenced about six years ago in the steelworks and laboratories of the Sheffield University College. The plan of campaign was to determine:—

1. The influence of chemical composition on the mechanical properties and micro-structures of steel castings.
2. The influence of annealing on the mechanical properties and structures.
3. The mechanical influence of variations in the specific gravities of steel castings.
4. The influence of process, namely, the difference, if any, between crucible and open-hearth castings.
5. The influence of mass—that is to say, the difference between the properties of large and small castings.
6. The influence of heat treatment on annealed and unannealed steel castings.
7. The influence of oil quenching on annealed and unannealed castings.
8. The influence of silicon and manganese on the heat of recalescence at the carbon change point, Ar1, the object of such observations being to obtain, if possible, thermal indications of the formation of double or triple carbides.
9. The relative properties of annealed castings and similar steels after forging.

CHEMICAL COMPOSITION.

In a research designed to ascertain the best standard composition for steel castings, it was, of course, neces [illegible]

mind the specifications at present issued by engineers to ensure high-class material. A common specification demands a maximum stress of about 30 tons per square inch—an elongation of 20 per cent. on 2 inches, and a bending angle on an inch square bar of at least 90°. In order to ascertain the influence of chemical composition on attaining, excelling, or falling short of the above requirements, it was decided to manufacture series of castings in three distinct chemical groups.

Group A.—Nearly pure iron and carbon castings, in which silicon, manganese, sulphur, and phosphorus should be kept low.

Group B.—Iron, carbon, and silicon castings, all other elements low.

Group C.—Iron, carbon, and manganese castings, low in other elements.

Group A.—Iron and Carbon Castings.

The group dealt with in the present paper is A., consisting practically of iron and carbon. This group, although perhaps the least interesting from a practical works point of view, is really of vital importance, because it forms the base-line from which alone the influence of the elements silicon and manganese can be accurately gauged. This fact does not seem to have appealed to some workers in the field of steel research, and in consequence much acrimonious, but unnecessary, controversy has resulted.

To include all the castings which have been made and tested in Group A. would inordinately lengthen the paper. The results set forth in Table I. must therefore be regarded as merely typical, and the castings therein have been selected to give a fair view not only of the influence of carbon on iron, but also to record a due proportion of those mysterious variations which set at defiance both the skill of the practical man and the science of the theorist. On reference to the table it will be seen that the series consists entirely of crucible steel manufactured from best Swedish iron. It will be shown in Part II. that it is quite unnecessary in general works practice to employ such a costly base. The castings were made in dry composition moulds in

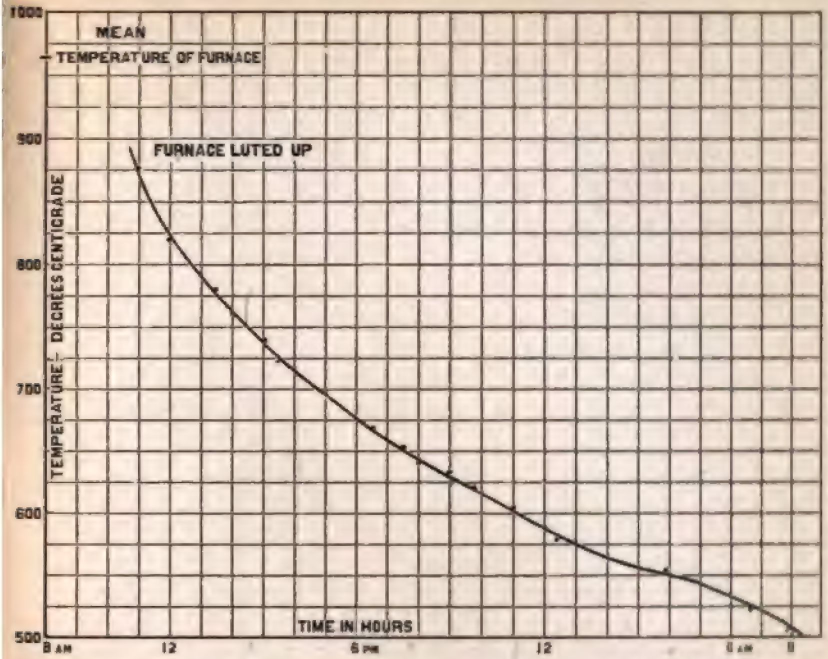


FIG. 2.—Cooling Curve of Annealing Furnace. (University College, Sheffield.)

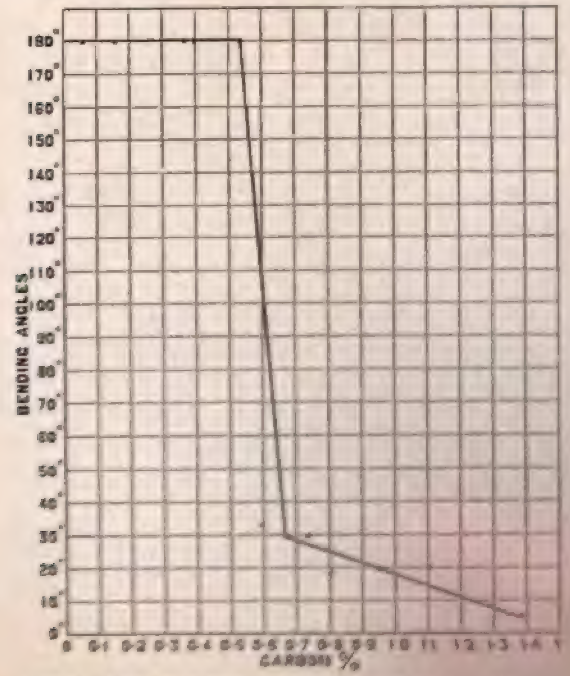


FIG. 3.—Bending Curve of Annealed Iron-Carbon [illegible]

the form shown in Fig. 1, namely, a group of four bars about 1⅝ inches round, and, of course, tapered to avoid "pulling." From the 3-inch round head four feeders arranged cruciformly lead to the actual bars, the whole group weighing about 28 lbs. Two of the bars were broken off to be annealed, the other two being tested as cast. From such a casting sets of test-pieces containing tensile, compression, bending and specific gravity pieces, together with micro-sections of the material both as cast and after annealing, are readily obtained.

FIG. 1.

It will be seen that in the seventeen castings selected as types for Group A., the carbon varied from 0·06 to 1·95 per cent. It is hardly necessary to add that only castings above suspicion as regards soundness were included.

Sizes of Test-Pieces.

Tensile.—0·564 inch diameter, or 0·25 square inch area, and 2 inches parallel.

Compression.—0·564 diameter, or 0·25 square inch area, and 2 diameters long.

Bending.—10 inches long and ¾-inch diameter.

Micro-sections.—Transverse only (the material being cast), ½-inch diameter by $\frac{1}{16}$-inch thick.

Specific Gravity.—Polished bars 2 inches long and ⅜-inch diameter.

METHOD OF ANNEALING.

The bars being somewhat small, it was necessary to protect them from undue scaling. They were therefore annealed in covered cast-iron boxes filled with quicklime. During the annealing process the boxes were maintained at a temperature of about 950° C. for about seventy hours. The castings were cool enough for drawing in about another hundred hours. The cooling curve of the furnace is shown in Fig. 2 (Plate IX.), the co-ordinate being time and temperature. The readings were taken every fi teen minutes by students working in shifts, and the temperatu

TABLE I.

The Properties of Small Iron and Carbon Castings moulded in Dry Composition.

Mark.	Process.	Analysis. CC.	Si.	Mn.	S.	P.	Al.	Tensile. Specific Gravity.	Elastic Limit. Tons per Sq. In.	Maximum Stress. Tons per Sq. In.	Elongation per Cent. on 2 Ins.	Reduced Area. Per Cent.	Bending ⅝-Inch Radius.	Compression per Cent. at 100 Tons per Sq. In.	Remarks.
FeB	Crucible	0·07	·023	·05	·02	·01	·018	7·9162	10·69	19·79	30·0	38·7	180° U	62·3	As cast
		0·07						7·9249	9·10	19·18	46·0	65·1	180° U	63·0	Annealed
473	,,	0·06	·06	·07	·02	·02	not estimated	7·9954	11·53	17·48	18·5	28·5	180° U	62·7	As cast
		0·06						7·9247	8·83	16·91	18·5	30·9	180° U	64·4	Annealed
521	,,	0·18	·01	·09	·027	·01	·023	7·8868	11·85	19·92	19·5	29·1	180° U	61·8	As cast
		0·16						8·0141	9·35	19·51	31·0	47·0	180° U	61·9	Annealed
458	,,	0·37	·05	·08	·03	·02	·02	7·9164	14·71	21·77	5·0	5·9	40°	55·5	As cast
		0·37						7·9761	10·28	20·84	12·5	19·8	180° U	58·9	Annealed
518	,,	0·37	·04	·10	·023	·017	·025	7·9842	15·95	23·22	6·0	6·3	32°	56·2	As cast
		0·37						8·0925	9·00	21·97	20·0	22·4	180° U	57·7	Annealed
CC	,,	0·42	·04	·06	0·2	·01	not estimated	7·8510	17·22	23·41	6·5	8·4	90°	45·7	As cast
		0·40						7·8653	10·08	24·03	24·5	29·0	180° U	50·0	Annealed
541	,,	0·44	·076	·03	0·3	·016	·032	7·9560	13·33	24·62	8·4	12·3	43°	57·3	As cast
		[illegible]						7·0782	12·21	23·50	14·0	16·0	180° U	62·3	Annealed

		0·54				mated	mated	8·0054	10·52	25·28	16·0	18·4	[illegible]	Annealed
517	,,	0·56	·08	·08	·031	·019	·037	7·8981	15·74	22·98	3·0	3·5	23°	48·6	As cast
		0·50						7·9644	12·32	25·32	10·0	10·0	135°	53·3	Annealed
536	,,	0·60	·073	·07	·031	·018	·028	7·9276	16·92	18·80	1·5	1·8	13°	51·0	As cast
		0·60						7·9533	9·80	16·49	2·0	2·4	33°	55·0	Annealed
631	,,	0·70	·11	·10	·045	not estimated	·050	7·8954	18·52	20·12	1·5	1·8	5°	47·2	As cast
		0·72						7·8612	13·92	30·32	6·0	5·3	30°	51·3	Annealed
459	,,	0·86	·06	·05	·02	·02	·018	7·9468	26·48	26·48	1·5	2·1	0°	broke at 54 tons per sq.in.	As cast
		0·80						7·9580	15·48	23·76	2·5	4·2	18°	45·4	Annealed
524	,,	0·97	·058	·03	·025	·018	·030	7·9054	22·25	32·42	2·0	1·8	8°	sheared at 90·4 tons per sq. in.	As cast
		0·83						7·9600	18·54	29·03	4·0	1·7	50°	50·7	Annealed
460	,,	1·29	·098	·28	·02	·02	·042	7·8788	22·30	22·30	0·0	0·0	0°	33·1	As cast
		1·10						7·8536	16·55	29·93	2·5	3·5	20°	40·7	Annealed
522	,,	1·35	·034	·02	·015	·016	·031	7·8454	13·18	13·18	0·0	0·0	0°	broke at 99·5 tons per sq.in.	As cast
		1·10						7·8771	12·86	12·86	0·0	0·0	3°	58·5	Annealed
	,,	1·76	·058	·07	·020	·022	·020	7·7424	20·32	20·32	0·0	0·0	0°	17·3	As cast
		1·38						7·7661	11·69	14·11	0·0	0·0	5°	52·7 sheared	Annealed

of the furnace during the annealing operation was pyrometrically controlled by experienced students.

It will be noted that the capability of the constituents to segregate ceases about twenty hours after luting up the furnace; in fact, the vital range of temperature in which is determined the ultimate structure of ordinary castings, namely, from 750° to 550° C., occupies only thirteen hours. The prolonged period of slow cooling from 550° to say 30° has little influence on the structure, but is highly necessary from a physical point of view in connection with the question of the unequal contraction of varying masses when cooled too quickly.

In spite of the precautions taken to prevent undue oxidation, it will be seen that during the annealing decided decarbonisation has taken place in the supersaturated castings, the figures given being the mean carbon of the tensile test-pieces. These results show how much more readily the carbon in cementite is oxidised than that in martensite.

Key to the Micrographic Analysis of Castings in Table I.

Mark.	Carbon.	Condition.	Micro-structure.
FeB.	0·07	As cast.	Pearlite and cementite practically absent. Irregular particles of pale ferrite mixed with about equal sectional areas of dark etching ferrite, looking almost like manganiferous pearlite. These darker areas evidently contain a minute quantity of finely divided carbide. Very drastic etching was necessary to bring up this structure, which looks almost like that of a 0·45 per cent. normal carbon steel. See Micrograph $\frac{473}{\text{as cast}}$ – $\frac{\text{FeB.}}{\text{as cast}}$
FeB.	0·07	Annealed.	On light etching isolated particles of laminated pearlite surrounded by and with offshoots of cementite showed themselves. The ferrite did not etch brightly, and the crystalline junctions were practically undeveloped. See Micrograph $\frac{473}{\text{annealed}}$ – $\frac{\text{FeB.}}{\text{annealed}}$ (Magnified 460 dias.) On deep etching the close crystalline joints became visible, showing here and there isolated bits of dark pearlite and streaks of cementite between the junctions. The ferrite crystals are very large, and sometimes exhibit within them parallel lines. See Micrograph $\frac{473}{\text{annealed}}$ – $\frac{\text{FeB.}}{\text{annealed}}$ (Magnified 200 dias.)
473	0·06	As cast.	Same as FeB as cast. See Micrograph.

Key to the Micrographic Analysis of Castings in Table I.—(Continued.)

Mark.	Carbon.	Condition.	Micro-structure.
473	0·06	Annealed.	Light etching brought up well-marked ferrite crystals, some pale, some grey-brown. A few isolated patches of laminated pearlite surrounded by cementite were also visible. Crystals rather small. See Micrograph. (Magnified 460 dias.) On deep etching the crystalline joints were very broad, presenting the appearance called by Sorby "loose." See Micrograph (magnified 200 dias.)
521	0·18	As cast.	Ground mass of small ill-defined ferrite crystals, with elongated or rounded patches of granular pearlite. Micrograph 521.
521	0·16	Annealed.	Ferrite crystals large and well defined. Pearlite in large isolated masses partly surrounded by cementite. Micrograph 521.
458	0·37	As cast.	Irregular trellis-work pattern of ferrite and pearlite.
458	0·37	Annealed.	Pearlite areas somewhat small and badly defined owing to segregation of the carbide striæ into massive cementite. Ferrite crystals not very large.
518	0·37	As cast.	Same as 458 as cast.
518	0·37	Annealed.	Large ferrite crystals and large well-marked pearlite areas.
CC	0·42	As cast.	The micro-section from this piece was lost, but from memory its structure was much as 458 as cast.
CC	0·40	Annealed.	Pearlite evenly distributed in somewhat small pieces enveloped to some extent in walls of cementite.
541	0·44	As cast.	Much as 458 as cast.
541	0·35	Annealed.	Much as 518 annealed.
CC2	0·48	As cast.	Irregular trellis-like pattern of mixed ferrite and granular pearlite. Long lines of ferrite broken in two longitudinally by dark-brown lines of sulpho-silicide of iron (?). See Micrograph.
CC2	0·50	Annealed.	Well-marked and moderately large iron crystals, with large segregated patches of laminated pearlite partly enveloped in cementite. See Micrograph. In another section from this casting the lamination of the pearlite areas was not so well marked.
JB	0·50	As cast.	Much as 458, but pearlite area larger.
JB	0·54	Annealed.	Same as 518 annealed, but pearlite areas larger and ferrite areas smaller in extent.
517	0·56	As cast.	Ordinary trellis pattern with some brown lines of sulpho-silicide of iron (?) in the ferrite. See Micrograph.
517	0·50	Annealed.	Large patches of ferrite and pearlite, the latter partly laminated, but often the pearlite laminæ had segregated into patches of massive cementite. See Micrograph.
556	0·60	As cast.	Trellis-work pattern of ferrite and granular pearlite, the latter being the greater in area.
556	0·60	Annealed.	Ferrite segregated from the pearlite in patches. Fe_3C in pearlite showing a tendency to segregate into patches rather than laminæ.

Key to the Micrographic Analysis of Castings in Table I.—(*Continued.*)

Mark.	Carbon.	Condition.	Micro-structure.
601	0·70	As cast.	Cells of granular pearlite surrounded by walls of ferrite. Patches of sulphide of iron concentrated into the ferrite walls were very distinct, evolving H_2S on etching.
601	0·72	Annealed.	Pearlite as such practically absent. Carbon distributed through the ferrite in rounded globules of Fe_3C.
459	0·86	As cast.	Ill-defined crystals of granular pearlite with small patches of ferrite. See Micrograph.
459	0·80	Annealed.	Laminated pearlite with some patches of white ferrite. See Micrograph.
524	0·97	As cast.	Granular or slightly laminated pearlite.
524	0·83	Annealed.	Granular or slightly laminated pearlite.
460	1·29	As cast.	Cells of granular pearlite enveloped in walls of cementite. Streaks of the latter also within the cells. See Micrograph.
460	1·10	Annealed.	Cells of laminated pearlite with envelopes of cementite; a few patches of sulphide of manganese visible. See Micrograph.
522	1·95	As cast.	Ground mass of granular pearlite cells with envelopes, streaks, and patches of cementite. See Micrograph.
522	1·10	Annealed.	Cells of ferrite dotted with little patches of cementite and surrounded by thick walls of cementite. See Micrograph.
573	1·76	As cast.	Much like 522 as cast.
573	1·38	Annealed.	Much like 522 annealed, except that nodules and thin rods of graphite are here and there visible.

Consideration of the Results—Specific Gravity.

The specific gravity results have been quite negative. The only noticeable feature is, that, as a rule, but not invariably, the specific gravity rises slightly on annealing, but speaking broadly no correlation has been established between the densities of the castings and their mechanical properties—a disappointing result, because much labour has been expended on this branch of the investigation.

Chemical, Mechanical, and Micrographic Correlation.

The two castings FeB and 473, both of nearly pure iron, both annealed under like conditions, present specimens of those almost disheartening discrepancies which the practical steel

metallurgist has from time to time to face. FeB probably constitutes a record for iron and carbon crucible steel castings. It is, after the annealing operation, to all intents and purposes equal to forged dead mild steel. On the other hand, 473 not only gave vastly inferior mechanical results, but was not mechanically amenable to the influence of annealing, although its structure was completely changed during the operation. In view of these facts, the micrographic examination was made as thorough as possible. In the steels as cast there existed little or no difference between their curious structures. (See Micrographic key.) After annealing, the intensely crystalline structure of 473 came up with very slight etching, whilst *cæteris paribus* no structure developed in FeB. On deeply etching the two under exactly the same conditions, FeB presented very large ferrite crystals with close joints, whilst 473 showed small ferrite crystals with loose junctions—that is to say, the etching acid developed broad spaces between them.

The present case is only one of many in the author's experience in which very large crystals have been associated with extreme ductility. This would seem to suggest that the condition of the joints rather than the size of the crystals is the important mechanical factor. But, however this may be, we are dealing with an effect rather than a cause. What is the cause which produces such differing crystalline and mechanical properties? Chemical analysis being practically the same and the annealing conditions identical, there remains only one other condition not under control, and that is the initial temperature of the casting. It would almost seem that this may determine a crystalline habit which survives even the drastic operation of annealing applied to steel castings. Whether this idea is well or ill founded can only be proved when scientific pyrometry can under practical conditions measure the temperature of molten steel, a feat which up to the present it has entirely failed to perform.

Passing to the next casting, 521, it will be noticed that increasing the carbon from 0·06 to 0·18 does not alter the elastic limit or maximum stress, and the ductility lies between the results registered for the good and bad dead mild castings, respectively FeB and 473. It will have been remarked that all

the castings hitherto considered have, both as cast and after annealing, bent double cold without flaw.

A reference to the micrographs of 521 as cast and after annealing will show that, as in the case of FeB, the annealed sample presents much larger crystals of ferrite and masses of pearlite than are present in the steel as cast. Nevertheless the ductility of the annealed is distinctly greater than that of the unannealed metal.

The very mild castings hitherto considered are, however, undesirable for general constructive purposes, and suitable only for dynamo work.

The next casting of the series, namely, 458, contains 0·37 per cent. of carbon, and the influence of this element now begins to make itself decisively felt by raising the maximum stress about 2 tons per square inch and much lowering the ductility, especially in the unannealed bars.

As the carbon in this casting is about the average amount employed for general work, three other castings, namely, 518 CC and 541 of similar carbon, were selected so as to make a series of four which should embody the variations met with in general practice with castings of almost identical chemical composition. Unfortunately, upon these mechanical variations the micro-structures throw little or no light. The mechanical discrepancies in nearly pure iron and carbon castings containing about 0·4 per cent. of the latter element may be thus summarised :—

In the metal *as cast*, the elastic limit varies from 13·3 to 17·2 tons per square inch, and the maximum stress from 21·8 to 24·6 tons. The elongation per cent. on 2 inches varies from 5 to 8·4, and the reduction of area per cent. from 5·9 to 12·3. The bending angles range from 32° to 90°.

In the *annealed castings*, the elastic limit varies from 9 to 12·2 tons per square inch, and the maximum stress from 20·8 to 24 tons. The ductility, as measured by elongation per cent. on 2 inches, varies from 12·5 to 24·5, and the reduction of area from 16 to 29 per cent. The annealed bars all bent double without flaw.

Passing now to about ½ per cent. of carbon, the casting CC2 exhibited very puzzling properties. The bars as cast fractured so suddenly that no difference was observed between the elastic

limit and maximum stress, although the slight elongation of 3 per cent. proves that some difference must have existed. The bending angle was trifling, being only 12°. On annealing, the elastic limit fell from 18 to 15 tons per square inch, whilst the maximum stress rose from 18½ to 26¾ tons. The elongation gave for 0·5 per cent. of carbon the high figure of 20·5 per cent., whilst the reduction of area was only 16 per cent. and the bending angle 86°. The result last named is quite abnormal. As a rule, a casting elongating 20 per cent. will bend double without flaw. A study of the micro-sections of CC2 will reveal vital principles connected with the mechanical properties of small unannealed castings low in manganese and high in silicon.

The brittleness of the unannealed bars seems due to two main causes. First, imperfect adhesion between the long, sharp junction lines of the constituents. Although the latter exhibit sectionally a trellis-like form, their solid geometry really consists of dark etching elongated cells of granular pearlite, surrounded by pale, thick walls of ferrite. But the second cause, namely, the brown lines running almost exclusively through the ferrite, and enclosing large groups of the two constituents, is distinctly the more potent factor producing brittleness. These lines of extreme weakness will be dealt with more fully under Group B., namely, the iron, carbon, silicon series; but it may be well here to make a few preliminary remarks on their nature.

Several years ago the author showed to his friend, Mr. J. E. Stead, these curious enveloping films, and at Middlesbrough Mr. Stead independently confirmed their existence in small castings. Both Mr. Stead and the author are agreed as to their fatal mechanical effects. Mr. Stead, however, is inclined to consider them of a scoriaceous nature, that is, a readily fusible dissolved slag segregating during cooling. The author has not been able to confirm this view, because before etching they are invisible, and hence apparently of a metallic nature. The author regards them as a fusible, metallic sulpho-silicide of iron, segregating in a minutely granular form. Indeed, Mr. Stead has, by differential sieving, obtained from castings exhibiting this phenomenon a residue high in silicon and sulphur. These envelopes are dangerous only in small medium carbon

castings; their more detailed description may be advantageously left until Part II. of this paper is reached, because by that time additional observations by other workers may be available to assist in deciding as to their actual nature.

In the meantime it may be remarked that the lines of these sectional meshes are often defined on etching by an evolution of sulphuretted hydrogen gas, which covers the iron adjacent to the lines with iridescent sulphide films. On annealing, these meshes are usually destroyed, running up into little isolated patches of pure sulphide of iron. (See Micrograph CC2.) The removal of these films, together with the destruction of the sharp, interconstitutional cleavage lines, largely accounts for the increase not only in ductility, but often also in tenacity observed after annealing steel castings, particularly those in which carbon and silicon constitute the bulk of the foreign elements present.

The author will in Part II. present the curious paradox that a small percentage of sulphur is actually more favourable to the production of the dangerous films just described than a relatively large amount of sulphur. With reference to the action of annealing on the carbide of 0·4 per cent. carbon steels, the following explanation, which excludes ultra-scientific theories, is practically and substantially accurate. On heating the casting in the annealing furnace to a temperature of about 700° C., the compound pearlite areas, which consist of 87 per cent. of iron intimately mixed with 13 per cent. of normal carbide of iron, Fe_3C, pass at Osmond's point, A_c1, into the simple constituent martensite, a highly attenuated but definite alloy corresponding to the formula $Fe_{24}C$. Then, as the temperature further rises between 700° and 800° C., the points A_c2 and A_c3 are passed, and the martensite and ferrite areas gradually interpenetrate until molecular equilibrium is established and the mass is homogeneous. On cooling, the constituents ferrite and martensite commence to segregate at about 750° C. and at 700° are distinct, the martensite having gathered into large irregular masses, and the ferrite into allotriomorphic crystals. At about 650° C. (Ar 1) the martensite, $Fe_{24}C$, decomposes into pearlite ($21\ Fe + Fe_3C$). Passing from 650° to 550° C., the Fe_3C segregates first into laminæ, then partially into imperfect envelopes surrounding the pearlite areas, and finally, if the

cooling be very slow, into isolated patches; so that pearlite proper has disappeared, and the areas it formerly constituted become really ferrite containing isolated globules of cementite. Whichever stage of the annealed structure ultimately remains, the mechanical quality of the castings is greatly improved, but in varying degrees. This subject will be better finally dealt with after the data on the heat treatment of unannealed and annealed castings have been presented.

Proceeding with the consideration of the results embodied in the table, the casting JB is reached, in which the carbon is a little over 0·5 per cent. This steel, when compared with CC2, presents some remarkable mechanical discrepancies in the annealed metal. The elastic limit is only 10·5 tons per square inch as against 15·2 tons in CC2. Although the elongation per cent. of JB is 4·5 per cent. lower than CC2, nevertheless JB has bent through 180° against the 86° of CC2. The micrographic analysis does not seem to reveal any differences in structure capable of accounting for these curious variations. Also in the case of 517 it will be noted that an elongation of only 10 per cent. is accompanied by a bending angle of 135.°

Passing next to 556, which contains 0·6 per cent. of carbon, it is evident that a critical mechanical point has been passed, accompanied by a decisive falling off in ductility, and in this particular casting the elastic limit and maximum stress are also very poor.

The carbon being well over the semi-saturation point (0·45 per cent.), the pearlite is now the predominating constituent, and in the annealed bars of 556 the pearlite had to a considerable extent decomposed into globules of cementite. It is therefore possible that, owing to their different co-efficient of contraction, these segregated cementite patches have partially detached themselves from the ferrite, thus forming innumerable flaws, which account for the unsatisfactory mechanical tests. But such a view is not easily reconciled with the properties of the next casting, 601, which contains 0·7 per cent. of carbon, and in the annealed sample of which the globular segregation of the pearlite laminæ into cementite is even more marked than in 556. It is true that 601 has little ductility, but its maxim[illegible] stress is over 30 tons, or nearly twice that of 556.

From 601, carbon 0·7 per cent., to 460 carbon, about 1·1 per cent., the maximum stress fluctuates from 24 to 30 tons, the latter evidently being the usual stress, the former the exception.

From 556 to the end of the series, ductility has practically vanished, if we exclude the slight recrudescence shown in the bending angle of 524, which curiously registered 50°.

522 and 573 show that very high carbon castings, both as cast and after annealing, can rank only with good grey iron castings.

The micrographs of 522 as cast and after annealing are interesting. It will be seen that during annealing a considerable amount of cementite was oxidised. In the annealed bar the residual cementite formed large cell walls, originally containing pearlite, but during the slow cooling the pearlite laminæ segregated into short thick plates, which no doubt, with still slower cooling, would have ultimately become isolated globules. In this case there is no doubt that, owing to their different contraction co-efficients, the cementite walls partially pulled away from the cells they envelop. In fact, this section is typical of a No. 5 cemented bar.

The remarkable mechanical variations so frequently referred to make it impossible to plot curves in which carbon is co-ordinated with the maximum stress or elongation, but taking the annealed bending tests and excluding the obviously abnormal cases of CC2 and 524, a curve is obtained which represents with approximate accuracy the influence of carbon on annealed iron castings. The results are plotted in Fig. 3 (Plate IX.), in which the co-ordinates are carbon per cent. and bending angles in degrees.

It will be noted that after the carbon reaches about 0·55 per cent. there is a sudden drop in the ductility, the latter, so far as practical test purposes are concerned, having virtually disappeared.

The compression tests call for no particular comment beyond remarking that the capability for compression falls with the carbon in the steel as cast from 63 per cent. in the nearly pure iron to 17·3 per cent. with 1·8 per cent. of carbon. After annealing, in the great majority of cases, the percentage of compression registered is only slightly increased, showing that the causes producing remarkable weakness in tension have relatively little effect when the material is in compression.

Heat Treatment.

Heat treatment, generally somewhat vaguely called annealing, is usually only of academic interest, but in the present paper it calls for consideration in view of the unfortunate fact that experimentalists are apt to generalise from laboratory results obtained with small plain bars, and put forward their data as available for guidance in works practice. In the majority of instances such a view is erroneous and misleading. It has been more than once urged that the annealing process used by the author is unnecessarily drastic, and if in practice only little bars such as are usually employed in laboratory practice were concerned, this criticism would be sound. But such is not the case. In large castings there often exist juxtaposed light and heavy masses. The former reach the maximum annealing temperature, say 950° C. or a light red heat, long before the heavy parts of the casting are anywhere near that temperature throughout their mass, and hence before such heavy parts are in a state of thermal and molecular equilibrium. It is therefore necessary to gradually soak such castings for prolonged periods, occupying not hours but days, in order to bring both light and heavy parts to a common temperature. It is also equally necessary to allow very gradual cooling, so as to avoid highly dangerous contraction stresses, which would inevitably be set up if such castings were allowed to cool in air.

Although the cooling condition just named has in the writer's experience given the best mechanical and structural results, it is, of course, quite inapplicable to large and complex castings.

Through the courtesy of Mr. Robinson, managing director, and Mr. Jobson, chief chemist, at Messrs. William Jessop and Sons, Limited, the author is able to bring before the attention of the Institute a curious incident observed by Mr. Jobson. During the annealing of a huge marine casting, the latter, as usual, had cast upon it in various parts several test bars. All but one of these gave excellent mechanical tests. Pieces of a good and a bad test bar were sent to the author for micrographic examination, and his results exactly confirm those of Mr. Jobson. The annealed structure of the good steel (carbon

and manganese 0·6 per cent.) consisted of a ground mass of ferrite, in which the areas formerly pearlite had passed into small, ill-defined particles of cementite. But the bad test bar showed the remarkable trellis-like section characteristic of brittle because unannealed castings. This structure is shown in the micrograph marked JB.

On investigation, Mr. Jobson found that this particular test bar, belonging to the bottom of the large casting, had been inadvertently buried in the sand on the bottom of the furnace; and hence its temperature had not risen above a low red heat, quite below the critical points. Therefore no diffusion of the constituents pearlite and ferrite, and consequently no recrystallisation, had taken place. Hence the structure remained practically as cast and the steel relatively brittle.

The following micrographic and mechanical data give typical results obtained by varying the thermal treatment of small castings. Four 1⅜-inch bars were cast as usual from nearly pure iron containing 0·36 per cent. of carbon.

Casting No. 660, *as Cast.*

The micro-structure was of the usual trellis-like sectional pattern, but for a low silicon casting the ferrite cell walls were permeated to an unusual degree with sulpho-silicide films.

The tensile test gave the following figures:—

Elastic limit, tons per square inch	13·34
Maximum stress, tons per square inch	13·34
Elongation (on 2 inches), per cent.	1·00
Reduction of area, per cent.	2·20

The material was thus little better than good grey iron.

No. 660. *Works Annealed.*

The micro-structure, as usual, showed a ground mass of ferrite crystals free from sulpho-silicide films, with relatively large patches of decomposed pearlite, *i.e.* pearlite in which the laminæ of Fe_3C had to a great extent segregated into little pieces of cementite.

The tensile test made on the works annealed bar gave the following results :—

Elastic limit, tons per square inch	9·34
Maximum stress, tons per square inch	22·24
Elongation, per cent.	14·30
Reduction of area, per cent.	15·00

The above is a poor result.

No. 660. As Cast and then Heat-Treated.

The bar as cast was slowly heated during about an hour up to 850° C. It was maintained for an hour at that temperature and then allowed to cool in air.

The micro-structure showed a ground mass of ferrite dotted with small particles of dark, granular ferrite. The sulpho-silicide films had disappeared, and the structure was much finer than that of the works annealed bar.

The tensile test was on the whole superior to that of the annealed bar, registering the following figures :—

Elastic limit, tons per square inch	14·34
Maximum stress, tons per square inch	26·76
Elongation, per cent.	13·50
Reduction of area, per cent.	18·60

No. 660. Works Annealed and Heat-Treated.

Another works annealed bar was treated in the manner described for the bar as cast.

The micro-structure was very similar to that last described, but distinctly smaller in pattern.

The tensile test was not altogether satisfactory, giving the following results :—

Elastic limit, tons per square inch	15·67
Maximum stress, tons per square inch	23·77
Elongation, per cent.	11·00
Reduction of area, per cent.	9·00

From the foregoing group of results it would seem that the ideal conditions for treating a brittle 0·4 per cent. carbon steel as cast are to heat it for an hour or so at a temperature about 50° above the upper critical point, and then cool in air. Unfortunately, in steel metallurgy the ideal and the practical are seldom synonymous terms.

Practical Summary.

The lessons taught by the data set forth in the preliminary experiments detailed in this paper show that pure iron and carbon steel is not a suitable material for fulfilling the modern specifications drafted by engineers for steel castings. With iron and carbon castings the ductility demanded can be ensured with ease, but with such ductility it is impossible to correlate the required tenacity. The latter property, it is true, can be obtained from iron and carbon castings, but at the expense of an almost complete loss of ductility. Therefore, as has already been remarked, excepting the nearly pure iron the series of castings described have small manufacturing interest. Nevertheless they form the basis upon which the mechanical influence of silicon and manganese, to be hereafter dealt with, can alone be scientifically measured.

The Comparative Properties of Castings and Forged Steels.

It has been previously pointed out that on rare occasions under certain, at present unknown, conditions of melting, steel castings may possess properties practically identical with those of forged steels of similar chemical composition. But such cases form the exceptions which prove the general rule, that the mechanical properties of annealed castings are much inferior to those of worked steels. This is the more remarkable because the same chemical composition, the same specific gravity, and the same micro-structure can be produced in a casting as in a forged steel, yet the mechanical properties of the latter will be enormously superior. It will be well to give concrete examples of these facts. The author, in a paper read before the Institution of Civil Engineers in 1895, fully described the properties of rolled iron and carbon steels. Comparative examples of those steels and the castings dealt with in the present paper present points of considerable interest, because the remarkable discrepancies exhibited are at present incapable of satisfactory explanation. The following tables embody the comparative properties of cast-and-rolled * and cast-and-annealed steels of almost identical composition:—

* The rolled bars when cold were reheated to about 1000° C. and cooled in air.

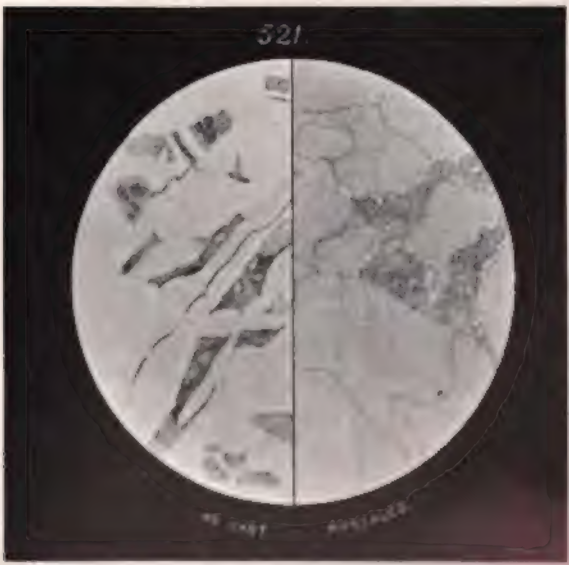
PLATE X.

Reduced from 6-inch circle. Magnified 200 diameters.

Reduced from 6-inch circle. Magnified 400 diameters.

PLATE XI

Reduced from 6-inch circle. Magnified 200 diameters.



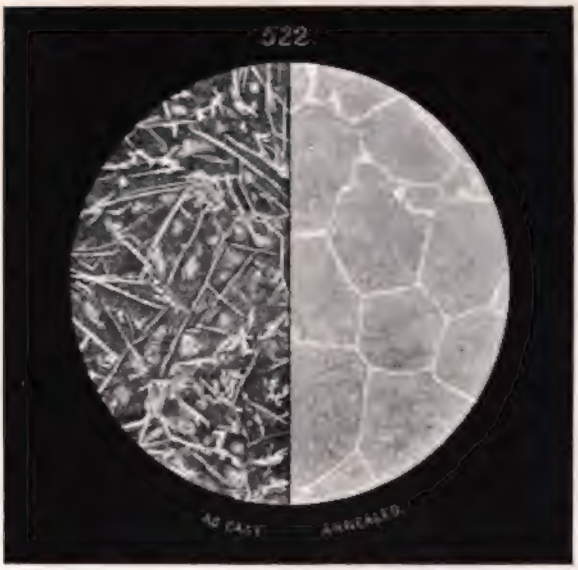
Reduced from 6-inch circle. Magnified 315 diameters.

PLATE XII.

Reduced from 6-inch circle. Magnified 315 diameters.

Reduced from 6-inch circle. Magnified 245 diameters.

PLATE XIII.



Reduced from 6-inch circle. Magnified 460 diameters.

Reduced from 6-inch circle. Magnified 460 diameters.

Reduced from 6-inch circle. Magnified 65 diameters.

Reduced from 6-inch circle. Magnified 65 diameters.

Conditions of Steel.	Carbon. Per Cent.	Elastic Limit. Tons per sq. in.	Max. Stress. Tons per sq. in.	Elongation. Per Cent.	Reduction of Area. Per Cent.
Cast and rolled	0·21	17·06	25·39	42·1	62·5
Cast and annealed	0·16	9·25	19·51	31·0	47·0

It will be seen at a glance that all along the line with reference to elastic limit, to tenacity, and to ductility the rolled steel is greatly superior to the annealed casting.

Passing to higher carbon the same relative characters are, if anything, still more decisively exhibited :—

Conditions of Steel.	Carbon. Per Cent.	Elastic Limit. Tons per sq. in.	Max. Stress. Tons per sq. in.	Elongation. Per Cent.	Reduction of Area. Per Cent.
Cast and rolled	0·38	17·95	29·94	34·5	56·3
Cast and annealed	0·40	10·08	24·03	24·5	29·0

When the carbon rises still higher, the differences are still most remarkable :—

Conditions of Steel.	Carbon. Per Cent.	Elastic Limit. Tons per sq. in.	Max. Stress. Tons per sq. in.	Elongation. Per Cent.	Reduction of Area. Per Cent.
Cast and rolled	0·89	24·8	52·4	13·0	15·4
Cast and annealed	0·83	18·5	29·0	4·0	1·7

Finally, in high carbon steel the rolled material still startlingly maintains its superiority :—

Conditions of Steel.	Carbon. Per Cent.	Elastic Limit. Tons per sq. in.	Max. Stress. Tons per sq. in.	Elongation Per Cent.	Reduction of Area. Per Cent.
Cast and rolled	1·20	35·72	61·65	8·0	7·8
Cast and annealed	1·10	12·86	12·86	0·0	0·0

The foregoing results should induce, in the minds of scientific metallurgists, a tinge of humility, because for some of them neither the scientist nor the practical man can offer any satisfactory explanation.

A noticeable practical feature on comparing the respective test bars is, that in the milder casting the fractures usually lack that fine grey granular appearance and cup-and-cone break which characterise mild rolled steels; also in castings the elongation is less confined to the vicinity of the fracture, being more evenly distributed along the bar, and hence accounting for the comparatively low reduction in area observed in castings when compared with similar rolled steels.

Castings frequently present incipient signs of fracture, *i.e.* small cracks, in places other than that at which the actual rupture takes place.

It will now be interesting to compare the effect of drastic annealing on steel as cast in small moulds and similar steel after rolling. On reference to the general table, it will be seen that casting 521, containing about 0·17 per cent. of carbon, showed after annealing a fall of 2½ tons per square inch in the elastic limit, a slight fall in the maximum stress, and a decisive increase in the ductility as measured by elongation and reduction of area per cent.

Under similar conditions of annealing, a rolled steel containing 0·21 per cent. of carbon showed a drop of no less than 8 tons per square inch in the elastic limit, a fall of about 4 tons in the maximum stress, whilst the elongation and reduction of area remained practically unchanged.*

Passing to carbon 0·37 per cent., casting No. 518, it will be found that again annealing has reduced the elastic limit, in this case no less than 6 tons per square inch. The maximum stress, however, fell only about 1 ton, whilst the ductility has greatly improved, the elongation rising from 6 to 20 per cent.

On annealing a rolled steel containing 0·38 per cent. of carbon, the general effect of annealing was similar to that observed in the 0·21 per cent. steel, namely, the elastic limit fell from 18

* See "Influence of Carbon on Iron." *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxiii. pp. 127–162.

to 9½ tons, the maximum stress from 30 to 25 tons, whilst the ductility was, if anything, slightly lowered.

With carbon about 0·9 per cent., casting 524, annealing somewhat lowered the limit and stress, and slightly raised the ductility. But on annealing a rolled steel containing about the same carbon, the elastic limit fell from 25 to 17 tons; the maximum stress from 52 to 36 tons, whilst coincidently with this great fall in tenacity, the ductility also underwent a remarkable decrease, namely, the elongation per cent. dropped from 18 to 4 and the reduction of area from 15 to 4. Hence, annealing beneficial to castings seriously injures rolled steels.

Thermal Data.

At the author's request, Mr. Andrew M'William, A.R.S.M., has kindly undertaken the recalescence investigations connected with this and the subsequent papers. His report on the iron and carbon groups is embodied in the following table. It will be more convenient to comparatively place the whole of the curves together in the final paper:—

Mark.	Carbon.	Heat Evolved at Ar 1 on Cooling.	
		Rise in Pyrometric Millimetres.	Equivalent Rise in Temperature of Steel.
FeB	0·07	0·4	1·2° C
521	0·18	1·6	4·8
518	0·37	5·1	15·3
459	0·86	16·0	48·0
460	1·29	11·2	33·6

The heats recorded in the above table were calculated by taking the total perturbation from the fair curve (whether occurring as an actual rise, stay, or retard) in seconds, and dividing by the mean rate. The result (being the equivalent rise in millimetres) multiplied by 3·0 (the calibration factor) equals the equivalent rise in the temperature of the steel in degrees centigrade. In steels 473 and 521 and 518, Ar 1 being separate on cooling, v calculated direct from the curve. In the other two cases

total heats of recalescence were calculated, and from them the sum of the heats evolved at Ar 2 and Ar 3 in FeB was subtracted.

In conclusion, the author has to thank Mr. F. Ibbotson, B.Sc., for the patient and accurate manner in which he has reproduced the micrographs illustrating this paper.

Of the work of Mr. F. K. Knowles it is difficult to speak in moderate terms. He has for several years patiently and vigilantly carried out the details of the practical manufacture, analysis, and mechanical testing of a very large number of castings, and well merits the thanks not only of the author, but of all interested in steel founding.

DISCUSSION.

Mr. R. A. HADFIELD, Member of Council, said he was sure that they all felt a great debt of gratitude to Professor Arnold for his excellent paper, which was only the commencement of very important research work upon which he had been engaged now for five or six years. They knew from the past work which Professor Arnold had put before the Institute that the research upon which he was at present engaged was bound to be of exceedingly great value, not only from a scientific point of view, but to the practical man as well. There was one point in the paper where Professor Arnold referred to the comparative qualities of forged and cast steel. It was quite true that in a number of cases the same uniform tests were not obtained from cast as from forged steel; but it was a question whether forged steel was so severely tested or submitted to so many exceedingly careful tests as cast steel. The casting maker had to run the gauntlet of a large number of inspectors, as Professor Arnold was aware. Taking the locomotive wheel centres alone, which used to be made of forged iron, cast steel had now entirely replaced the latter material. That, he thought, was a satisfactory proof that on the whole cast steel could be relied upon for a large number of purposes in an equally safe manner as forged iron or steel. As regards this research work, in order to thoroughly appreciate the value of the paper they must wait for the concluding portions mentioned, when it would be possible to offer more full criticism. Professor Arnold had stated in his opening remarks that the series of tests in this case were carried out upon an alloy of iron and carbon. That, as the Professor pointed out, was not a commercial product. All steel castings contained a certain amount of silicon and manganese, and nowadays very often there was a third element. He very heartily agreed in a remark which Professor Arnold made in the paper where he said with regard to iron and carbon castings: "This group, although perhaps the least interesting from a practical works point of view, is really of vital importance, because it forms the base line from which alone the influence of the elements silicon

and manganese can be accurately gauged." He would like to suggest, as the Institute was going to make use of the fund which Mr. Carnegie had so generously placed at their disposition, that in research work experiments submitted to the Institute a rule should be laid down that all the samples, whether cast or forged, must be accompanied with the complete, and not merely a partial, analysis—carbon, silicon, sulphur, phosphorus, manganese, and any special elements. Speaking personally, he might say that in many papers submitted to the Institute, he had often tried in vain to compare one result with another, simply because certain portions of the analysis were missing, and, as Professor Arnold pointed out, that was exceedingly unfortunate, because it might often happen that the missing element which was not stated might make all the difference. It was the same with regard to mechanical tests. These were often incompletely given, and much valuable work often rendered of little service. An excellent paper had been read before the Institute yesterday; but as regards one of the specimens described one point was omitted—namely, the elastic limit, and the results were thus much reduced in comparative value. Therefore he suggested that they might state to intending candidates for the Carnegie prize that complete information must be given in the research work and that incomplete analyses or tests could not be accepted. Nowadays both chemical and mechanical tests were readily obtained; therefore there was no excuse for laxity in this respect.

Professor Arnold, in referring to large crystals, used an expression, viz., "crystalline habit," which he thought was an excellent new term, and he hoped it would often be used in describing certain peculiarities met with in steel. He himself, in making alloy specimens, had met with the character of the structure referred to by the Professor, and he must say that up to the present time a satisfactory explanation was not forthcoming. In making alloy steel, such as manganese steel, it was quite possible to obtain a strong crystalline structure which no amount of annealing would remove. He hoped Professor Arnold, who had special opportunities and leisure, would continue to investigate and follow up that important point.

Professor Arnold had also mentioned another curious point which had often puzzled him in his own investigations; that

was, that good bending tests were often obtained from samples, and yet the elongation did not at all correspond with the high bending angle. As will be noticed, nearly all the samples to which the author referred bent double cold, and yet the elongation of some of the same specimens was comparatively small. It was very singular that this should be so.

He again offered his hearty congratulations to the Professor on the opening paper of his very important research work.

Mr. F. W. HARBORD said they must all congratulate Professor Arnold on the thorough way in which he had started his investigation. The only way to succeed was to start at the base line and gradually work up to the conditions of actual practice. With reference to the temperature of annealing, he would like to ask why the particular temperature of 950° had been selected for all grades of carbon steel? He thought that was rather high. He was keenly interested in this question of temperature, as he had been working at it for some time, and a great many practical steelfounders had given him information as to the temperatures which they found to give the best results in actual practice. In all cases it had been distinctly lower than 950° C., and especially was this the case for high carbon steels. In fact, it seemed the universal practice, as far as his information went, that at those works where they took accurate measurements, the higher the carbon in the steel, the lower the temperature of annealing. He thought that was borne out by those working tests which Professor Arnold had referred to, as the author stated there that the annealing temperature was 850° C. as against 950° C., the temperature employed in the experimental work. It was possible when Professor Arnold had completed the programme mapped out, he might find it advisable to make a series of experiments on the effect of varying the temperature, but apparently he did not at present propose to do so. In the paper the author referred to the action of annealing on steels with 0·40 per cent. of carbon, and offered an explanation which, he stated, had the advantage of excluding all ultra-scientific theories, and which, he said, at the same time was practically and substantially correct, certainly two most important things. According to the author's hypothesis, on annealing

700° at Osmond's point Ac 1 the pearlite passes into "the simple constituent martensite, a highly attenuated but definite alloy, corresponding to the formula $Fe_{24}C$." And he further stated: "At about 650° C. (Ar 1) the martensite, $Fe_{24}C$., decomposes into pearlite ($21Fe + Fe_3C$)." This he understood to be a perfectly definite statement that martensite had the formula of the sub-carbide $Fe_{24}C$, and he would be glad if the author would give his reasons for this conclusion, as without these it was impossible to form an opinion as to how far this was practically and substantially correct. He assumed the author's conclusions were, at all events in part, deduced from what was found to be the structure of steels when quenched from certain temperatures; but if they examined a steel containing 0·40 per cent. of carbon quenched from 800°, it consisted entirely of martensite, which, if the author was right, and had the composition of $Fe_{24}C$, would require nearly 1·00 per cent. of carbon instead of 0·4 per cent.—that actually present. In other words, if martensite was $Fe_{24}C$, a quenched sample of 0·40 per cent. carbon must contain less than 50 per cent. martensite, whereas it had been clearly shown by Sauveur that under certain conditions it might contain 100 per cent., and consequently there was not enough carbon to go round in a 0·40 per cent. carbon steel to form this quantity of $Fe_{24}C$; so that from the evidence at present before them it did not seem possible it could have this particular composition, $Fe_{24}C$.

Mr. F. H. LLOYD asked the author if in his investigations he had noticed a difference between what he might call proper annealing, and simply heating and laying off to cool in the open.

Mr. E. F. LANGE asked the way in which the author prepared his pure iron and carbon castings. He presumed that aluminium was required. Several other points had struck him with regard to the data given as to the basis for the experiments. To the three chemical groups mentioned by Professor Arnold he would suggest that he should add a fourth—namely, one in which the carbon was kept within low limits—say, from 0·20 to 0·30, and with both silicon and manganese in variable proportions.

With regard to the annealing experiments, the time of soaking given at the temperature of 950° C. would be a drawback in ordinary foundry practice on account of the excessive scaling which this would cause. He was somewhat surprised to find that Professor Arnold had used the same annealing temperature for such a wide range of composition as from carbon 0·07 per cent. to carbon 1·95 per cent. He missed also any inclusion of Brinell's theories. Those theories, in his experience, applied equally well for castings as for forged steel—namely, the desirability of dividing the annealing operation into two parts, the first destined to produce a fine crystalline form, and the second directed towards converting the carbon from the hardening to the cement condition, the temperature required being altered to suit the various grades of steel. Mr. Hadfield had brought out the importance of this point in the discussion upon Mr. Sauveur's paper upon the "Relation between the Structure of Steel and its Thermal Treatment," at the Manchester meeting in the autumn of 1899. If any doubt yet remained as to the value to the steel manufacturers of microscopic research, surely the present paper would remove that doubt.

CORRESPONDENCE.

Mr. J. E. Stead, Member of Council, regretted that he was obliged to leave the meeting before the discussion on the author's paper, and sent the following communication:—It was perfectly true, as the author pointed out, that in small castings the crystalline grains of steel were sometimes separated from each other by a more or less complete envelopment of what he (Mr. Stead) had described as scoriaceous matter, for want of a better name. From a practical point of view it was immaterial whether the substance was called scoriaceous matter, sulpho-silicide of iron, sulphide of manganese, or silicate of manganese, as, whatever it was, it separated the grains one from the other, and was itself exceedingly brittle and had little coherence, and must necessarily cause structural weakness of the whole mass. He (Mr. Stead) had separated silicates of manganese and sulphide of manganese

from steel, and found that they were often associated together, one being a palish green and the other a slate colour. He would be glad to know if the author had separated, isolated, and proved the existence of the sulpho-silicide of iron.

Mr. F. DAVENPORT, Salford, requested the author to state whether he did not think the best result with No. 660 would have been obtained by heat-treating, and cooling slowly instead of cooling in air. Also was the comparison between rolled and cast steel made with precisely the same quality of steel—that is to say, with crucible steel made with the best Swedish material.

Professor ARNOLD, in replying on the discussion, said that he fully agreed with Mr. Hadfield that excellent steel castings were now produced; in fact, during the last fifteen or twenty years great strides had been made in improving the quality of such material. At the same time, as Mr. Hadfield remarked, rolled steels gave the more uniform results.

With reference to the criticism of Mr. Harbord, he would remark, that the temperature of 950° had been selected because it safely cleared the change point Ar_3 in the mildest steel investigated, and for comparative results on carbon steels it was necessary to employ a uniform temperature. As a matter of fact, this temperature was commonly reached in works practice. He could not agree with Mr. Harbord in his statement that the higher the carbon the lower the temperature of annealing; and in any case, the remark did not seem to have any bearing on steel castings, which seldom exceeded 0·5 per cent. in carbon. It might, however, interest Mr. Harbord to know that the prolonged experience of one of the most experienced metallurgists in Sheffield had led him to the conclusion that 950° gave in the case of crucible steel good results, with, say, 0·6 per cent. carbon steel, and also with, say, 1·3 per cent. carbon steel, but that with 0·9 per cent. carbon steel a lower temperature, about 850°, was necessary to avoid producing brittleness. This fact confirmed the result described by the author in the paper read before the Institution of Civil Engineers on the influence of carbon on iron. Mr. Harbord remarked, that he (the author) did not seem to intend to investigate the influence of varying temperatures.

Surely Mr. Harbord did not think it worth while to waste work on material which he (the author) had pointed out was not suited for commercial work. Mr. Harbord would find the matter fully dealt with in the next paper, for which most of the work was already finished.

In his remarks about martensite, Mr. Harbord practically intimated that he considered the author was lacking in a knowledge of elementary arithmetic. The author had never in any way made the assertion attributed to him by Mr. Harbord, that a 0·4 per cent. carbon steel quenched out consisted of $Fe_{24}C$. Mr. Harbord actually quoted that it had been clearly shown by Sauveur that 0·4 per cent. carbon steel when quenched was entirely martensite. Mr. Sauveur had never shown this to be so. The steel upon which he experimented contained 1·2 per cent. of manganese and 0·3 per cent. of silicon. If Mr. Harbord would take the trouble to quench such a steel containing only carbon, he would find that it consisted of an intimate mixture of dark martensite and pale ferrite.

An experiment such as mentioned by Mr. Lloyd would be found in the paper (p. 191).

In reply to Mr. Lange, it would be found in the final page that the group mentioned by Mr. Lange would be derived as a matter of logic from the results obtained from the other groups already mentioned. He thought that to saddle Mr. Brinell with any responsibility for castings on the results Mr. Brinell had obtained on forged steels would be not only unjust to Mr. Brinell but also inaccurate. The results he had obtained did not bear out Mr. Lange's views. The carbon would be converted entirely from the hardening to the cement condition, even with very thin sheets cooled in air, as had been clearly shown by Sir F. Abel.

In reply to Mr. Stead, the author had not in any way isolated a sulpho-silicide. The name was tentative as most likely on the evidence extant, viz., that the alloy certainly contained sulphur and was most developed in a silicon state.

In reply to Mr. Davenport, the author did not think that on slow cooling with No. 660 the tenacity would have been so high as when cooled in air, though the ductility would have been somewhat greater.

The PRESIDENT moved a vote of thanks to Professor Arnold, which was unanimously accorded.

The PRESIDENT then stated that the remaining papers would be taken as read, and those members who desired to discuss them could do so in writing.

On the motion of the PRESIDENT, the thanks of the Institute were accorded to the authors of the papers.

On the motion of the PRESIDENT, seconded by Sir LOWTHIAN BELL, Bart., Past-President, a vote of thanks was also passed to the President, Council, and Secretary of the Institution of Civil Engineers for the use of their rooms for their meeting.

Sir EDWARD CARBUTT, Bart., Member of Council, moved a vote of thanks to the President for his conduct in the chair. This was seconded by Mr. W. R. WEBSTER, of Philadelphia, and unanimously carried.

The proceedings then terminated.

The papers taken as read were as follows:—

NOTE ON A MEDAL STRUCK IN STEEL PRESENTED TO THE INSTITUTE BY MR. E. J. LJUNGBERG.

BY BENNETT H. BROUGH, SECRETARY.

MR. E. J. LJUNGBERG, general manager of the Stora Kopparbergs Company of Sweden, presented to the Iron and Steel Institute on January 23, 1901, a medal struck at the Swedish Royal Mint in soft basic steel from the Domnarfvet Steelworks. As this is the first medal that has been struck in steel, it has been thought that some particulars of its composition and of the occasion on which it was struck might usefully be recorded in the Institute Journal.

The medal is $2\frac{1}{4}$ inches in diameter, $\frac{1}{8}$ inch thick. On the obverse there is a profile bust of Mr. Ljungberg with the inscription: "ERIK·JOH·LJUNGBERG·ST.·KOPPARBERGS·BERGSLAGS·DISPONENT·FRÅN·ÅR. 1875. 1 NOV. 1900"; and on the reverse two sprays of fir tied together with a ribbon, with the alchemical symbol for copper and the inscription: "BERGSLAGS·TJENSEMÄNNENS TACKSAMHET" (Plate XV.). The soft basic Bessemer steel of which the medal is made contains:—

	Per Cent.
Carbon	0·05
Manganese	0·19
Silicon	0·007
Phosphorus	0·002
Sulphur	0·005

On November 1, 1900, Mr. Ljungberg celebrated the twenty-fifth anniversary of his appointment as general manager of the Stora Kopparbergs Mining Company. On that occasion the company presented him with a highly artistic souvenir in the form of two maps enclosed in one frame, $6\frac{1}{2}$ feet high and 4 feet broad, made in silver and gold from the Falun mines, inlaid with ivory, enamel, and precious stones. The whole was designed by Mr. A. Lindegren, the figures being designed and modelled by Mr. V. Andren and Mr. A. Olsson. The trophy weighs 330 lbs.

At the same time the officials of the Company presented a medal struck in gold from the Falun mines. The dies for this medal were engraved by Professor A. Lindberg. Subsequently it occurred to Mr. Ljungberg that it would be an interesting experiment to ascertain whether from these dies a medal could be struck in basic steel. The experiment proved successful, and the resulting medal was presented to the Iron and Steel Institute.

The works of the Stora Kopparbergs Mining Company at Falun, Domnarfvet, and Skutskär were visited, it will be remembered, by the Iron and Steel Institute in 1898. The Company is the oldest joint-stock enterprise in the world. There is still in existence in the State archives a deed for the transfer of shares in the Company dated 1288, and the royal charters, which refer to the Company as being then very ancient, bear dates from 1347 to 1432. The real estate of the Company comprises vast forest, copper and iron mines, and waterfalls representing 100,000 horse-power. Dating from its oldest charter, the Company celebrated on February 24, 1896, its 550th anniversary. The Company is naturally proud of its history, and preserves in its museum at Falun a number of antiquities and relics of the greatest interest. From its celebrated copper mine at that town the Company derives its name of The Great Copper Mountain (Stora Kopparberg). Its first ironworks, Svartnäs, were built in 1735, and some twenty other small works were soon added. Owing to difficulties in manufacturing economically at so many small works, it was decided in 1873 to concentrate the manufacture at Domnarfvet, by one of the big waterfalls of the river Dala. These ironworks are the largest in Scandinavia, and the largest ironworks using charcoal fuel in the world. They possess a charcoal-burning plant with eight large kilns, a blast-furnace plant with four furnaces, six Westman calcining kilns, and seven Cowper hot-blast stoves, five Bessemer converters (two of 6 tons and three of 5 tons), four open-hearth furnaces (each 15 tons), a rolling-mill plant, forge, plate-pressing works, and a horseshoe-nail factory. Every variety of pure iron and of the highest grade of steel is made, the annual production being 55,000 tons of pig iron, 35,000 tons of Bessemer ingots, 26,000 tons of open-hearth ingots, 3000 tons of charcoal

iron blooms, 47,000 tons of rolled and hammered iron and steel of all kinds, and 600 tons of horseshoe-nails. The basic process was adopted in 1891 for a portion of the out-turn, the three 5-ton Bessemer converters and two 15-ton open-hearth furnaces being used for basic work. The iron produced, being made with charcoal from ores free from phosphorus for the acid process, and free from sulphur for the basic process, is of remarkable purity. Indeed, the average percentage of phosphorus in the Bessemer and open-hearth pig iron made during the last three years was only 0·019 per cent. The reason why so many different methods of manufacture are in use is that there is a great diversity of ores available, the Company being large owners of the phosphoric ores of Grängesberg, as well as of remarkably pure ores of other localities.

During Mr. Ljungberg's management, in the years 1875 to 1900, the Company has made conspicuous progress. The Domnarfvet ironworks were started in 1878, and have several times been enlarged and partially rebuilt. The Skutskär sawmills were purchased in 1885, and have since been remodelled. The present production is about 50,000 St. Petersburg standards of sawn and planed stuff. In consequence of a discovery of native gold in the Falun mines in 1881 a new metallurgical process was introduced at the Falun gold and silver works in 1885. The gold production, which averaged from 1 to 3 kilogrammes before 1875, has risen to about 100 kilogrammes at the present time. The Skutskär sulphate pulp works were built in 1894. The annual production is 15,000 tons of sulphate cellulose. The Domnarfvet charcoal plant was built in 1894. The annual output is now 2,000,000 bushels of charcoal and 1300 tons of by-products. The Kvarnsveden power station was built in 1900. Its turbines have 18,000 horse-power. The Domnarfvet paper works were begun in 1898 and finished in 1900; the output is 30,000 tons of paper. The Skutskär sulphite works were begun in 1900 and started in February 1901. The works will produce 15,000 tons of sulphite cellulose. The Falun sulphuric acid works were rebuilt in 1899. The annual output is 3000 tons of concentrated acid.

CORRESPONDENCE.

Sir JOHN EVANS, K.C.B., F.R.S., President of the Numismatic Society, considered that the steel medal presented to the Institute by Mr. Ljungberg was of considerable interest, if only as showing that the process usually applied to the production of steel dies was equally applicable to the production of a medal. It seemed rather unfortunate that no details were given as to the manner in which the medal had been struck. It did not appear whether it was finished at a single blow in the coining press, or whether it had required to be submitted several times to the dies, being annealed between each operation. Under any circumstances, it was, so far as he was aware, the first example of a medal, whether of large or small size, struck in basic Bessemer steel.

According to ancient historians, iron money was in use at Sparta and at Byzantium, but it has been suggested that the currency was in the shape of bars rather than of coins. At present no example of a Byzantine or Spartan coin made of iron was known. Nor had any been found of Clazomenæ, where Aristotle says that iron money was current. On the other hand, there existed an iron coin of Argos, of which an electrotype was in the British Museum. It was probably struck "while the iron was hot." Others of Tegea and Heræa had also been mentioned.

In recent times in Japan* small coins had been cast in iron, representing the thousandth part of a silver dollar. Their principal use was for devotional offerings or for alms to beggars.

Mr. WARWICK WROTH, of the Department of Coins and Medals in the British Museum, stated that instances of iron being used for coins were very few in number, and the extant specimens were of extreme rarity. The British Museum had none in its possession. The only specimens known to the writer were of Southern Greece, of the fifth or fourth century B.C. There were also in existence two iron coins, one supposed to be

* *Numismatic Chronicle*, 1880, N.S., vol. xx. p. 174; and *Proceedings*, 3rd Series, vol. ii. p. 342.

PLATE XV.

MEDAL STRUCK IN STEEL.

Presented to the Iron and Steel Institute by E. J. LJUNGBERG.

of the Bactrian king Hermæus, which had been described by Gardner.* These were brought by Sir Douglas Forsyth from Kashgar.

Mr. E. BRUSEWITZ, Director of the Swedish Royal Mint at Stockholm, in reply to a request for further particulars, communicated the following notes on the method employed in striking the steel medal. The possibility of striking medals in this material first suggested itself to Mr. Ljungberg, the manager of the Domnarfvet Steelworks, on account of the extreme softness of the Bessemer steel produced at his works, when containing below 0·10 per cent. of carbon, and he (Mr. Ljungberg) had asked him his opinion on the matter. He had replied that though no doubt the experiment would succeed if executed with sufficient care, he could not be answerable for the dies, on account of the liability of the latter to become worn or crushed in dealing with a material so much harder than that usually employed for striking medals. With this reservation the experiment was made, with entirely satisfactory results. The steel medal was struck in exactly the same manner as other medals of gold, silver, or bronze. It should be mentioned that before being placed between the dies, the blank was annealed and cooled, and then carefully washed and dried. After one or two blows in the medal press, the metal became so hard that it could receive no further impression from the engravings of the dies, and it was necessary to anneal and cool it a second time before replacing it between the dies. This was repeated three or four times before obtaining a sharp and perfect impression of the engraving. The number of strokes required will be found to depend on the depth of the engraving, the softness of the metal used, &c. In striking a medal in steel, the material, of course, does not so readily flow out into the engraving of the dies as is the case with bronze, but in striking medals with a low relief, such as that struck in celebration of Mr. Ljungberg's twenty-fifth anniversary, the difference is insignificant. Four annealings and as many blows were found to be sufficient for this medal, a similar number of strokes, though less heavy, being required for a bronze medal of the same kind. On finding that no injury was done to the dies by applying the usual

* *Numismatic Chronicle*, 1879, p. 274 *f.*

pressure, a number of steel medals were subsequently struck with equal success. Open-hearth steel from the Fagersta steelworks had also been used for this purpose, and medals of various sizes were struck from this metal, as well as from the basic Bessemer steel from Domnarfvet. An interesting point, though one that might have been expected, was that while the number of annealings for a steel medal with a low relief was the same as for one struck in bronze with the same dies, yet when it was desired to produce a medal with a very high relief, the steel had to be annealed more often than the bronze. In conclusion, the results of the experiments showed that, notwithstanding the fact that the softest steel is much harder than bronze containing 92 per cent. copper and 8 per cent. zinc, the difficulty of striking steel medals as compared with bronze medals was not so very great.

THE HEAT OF FORMATION OF CARBIDES AND SILICIDES OF IRON.

By E. D. CAMPBELL (University of Michigan).

In a recent paper, "The Theory of Solution of Iron and Steel," * Baron Jüptner states that two of the objects of his study are to point out "what conclusions the present available experiments promise to give, and to invite search for those fundamental data which are yet wanting for a vigorous employment of theory." Any results which increase our knowledge of the heat of formation of the compounds of iron with carbon and silicon will therefore be of interest, and it is for this reason that I would submit to the Institute some of the results which have been obtained in this laboratory during the past three years.

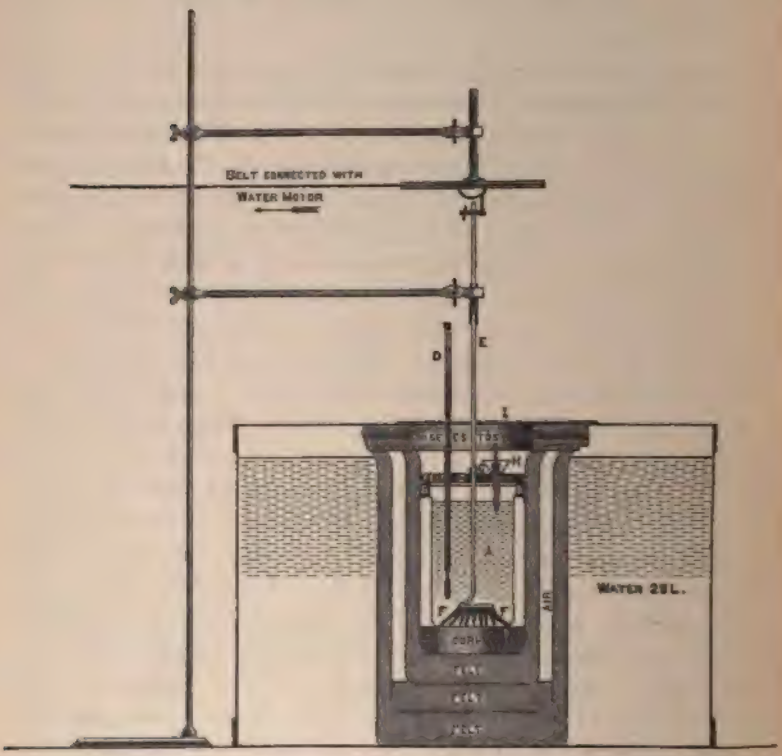
In 1897 Mr. F. Thompson undertook a thermo-chemical study of iron and steel in this laboratory. The results which Mr. Thompson alleged to have obtained showed even as great a variation in the heat of solution of iron and steel of various composition and mechanical or heat treatment as those reported by Mr. Osmond,† on which Baron Jüptner bases his calculations and conclusions. The results of Mr. Thompson's work were published in the autumn of 1897, but almost as soon as published, suspicion was aroused as to the reliability of the figures, and a "Correction" was therefore at once published requesting that judgment on the article be withheld until we could carefully review the work. This review of the work was begun in the autumn of 1897, and carried on by my successive assistants, W. E. Hartman, C. Sundström, and E. C. Champion, working mostly independent of each other during a period of a little over two years. During this time efforts were made to eliminate experimental error. To this end improvements in the mechanical details of the calorimeter were made, the correction for

* *Journal of the Iron and Steel Institute*, 1900, No. I. p. 219.

† *Comptes Rendus*, vol. c. p. 1228, and *Annales des Mines*, vol. viii. p. 1.

loss by radiation carefully determined, as well as the slight gain due to the oxidation of cuprous to cupric chloride by dissolved air.

The calorimeter employed in the work is shown in the accompanying sketch. It consisted of four concentric beakers separated from each other by two felt and one dead air space, the whole contained in an outer jacket filled with water. The inner beaker



contained at the bottom a cork ring on which the solution beaker (A) stood; this latter was prevented from coming in contact with the sides of the inner beaker by means of three strips of cork (B), which also served to support the lower cover (C). This latter consisted of two discs of hard rubber separated by about half an inch of felt, which projected just enough to make a close fit with the inner beaker. The cover, which was provided with a wire

handle, was perforated by three holes; through the first was inserted the Beckmann thermometer (D), having a range of six degrees with graduations in hundredths of a degree. Through the second hole passed the stirring rod (E), which could readily be connected at its upper end with a pulley actuated by a water motor imparting to it a speed of 130 revolutions per minute. The lower end of the stirring rod was bent in such a form as to impart a rotary motion to the solution, and was provided with a number of small fingers (F) made of pure rubber cemented to the rod in such a way that they would lightly sweep the entire bottom of the beaker. The extent to which these fingers brushed the bottom of the beaker was determined by means of the small rubber collar (G) attached to the stirrer just above the cover (C). This device of rubber fingers brushing the bottom of the beaker rendered the complete solution of the sample much more rapid than could be obtained by any other method tried. Through the third hole of the cover was inserted a small funnel (H), the stem of which was cut to such a length that it dipped an eighth of an inch below the surface of the solvent. This funnel was provided with a plunger (I), which made a close fit with the stem of the funnel. Through the funnel the sample could be easily and quickly introduced, the plunger serving to push in the last particles, thus insuring complete delivery of the powder beneath the surface of the solvent and avoiding any error due to the floating of any small particles. All samples operated upon were first reduced by suitable means, such as filing, grinding, or crushing, so that the entire sample would pass a sieve of eighty meshes to the linear inch. The entire apparatus, calorimeter, stock solutions of the various solvents employed, as well as the balance for weighing out the solutions, was kept in the basement in a constant temperature room which could easily be kept within about one degree.

The rate of loss by radiation was determined by first placing in the beaker (A) enough water to fill it nearly to the full depth employed; this was allowed to stand over night until all had come to a constant temperature, the stirrer was then set in motion, and when the thermometer showed a perfectly constant reading, a small amount of warm water was poured in by means of a drawn-out funnel, the amount introduced varying so that the

temperature of the solution in the beaker was raised during different experiments from 0·5° to 3·5°, by intervals of about 0·5° each. A fresh solution was employed for each experiment, and allowed to come to a constant temperature before the addition of the warm water. After each addition of the warm water, thermometer readings were taken each minute for about twenty minutes; from this series of readings the mean rate of loss by radiation was calculated for each 0·1° difference between the initial and final readings. This rate of loss by radiation for intervals of 0·5° between the initial temperature and the thermometer readings is shown in the following table:—

Difference in Reading. Degrees C.	Loss per Minute. Degree C.
0·5	0·003
1·0	0·006
1·5	0·008
2·0	0·010
2·5	0·0125
3·0	0·0150
3·5	0·0180

Whenever a sample was dissolved, readings were made at the end of each minute, and the total amount of heat lost by radiation during the time of solution was estimated and this correction introduced in the final calculation.

The second correction due to the oxidation of cuprous chloride to cupric chloride by dissolved air was determined by dissolving 1·135 gramme of pure copper, the chemical equivalent of one gramme of iron, and observing the thermometer readings. Experiments showed that the solution to cuprous chloride was complete within three minutes, but owing to the oxidation of this cuprous chloride the thermometer continued to rise slowly for a long time. This rise of temperature amounted to 0·005° per minute during the first ten minutes, and then gradually fell off, until at the end of twenty minutes it was only about one half this rate. Since almost all samples of iron and steel operated upon required much less than ten minutes for complete solution, the correction for oxidation of cuprous chloride to cupric chloride became proportionate to the time of solution. The solution of ammonium or potassium cupric chloride employed was nearly saturated, containing 300 grammes of the crystallised salt per litre.

The most important discovery made was that crystallised carbide of iron is practically unacted upon by a neutral solution of either ammonium or potassium cupric chloride, and that the solubility of the carbide is increased with the fineness of subdivision. If, however, the solution of ammonium or potassium cupric chloride contains less than one per cent. of free hydrochloric acid, the carbide of iron, even though coarsely crystalline, will dissolve completely within two minutes. Messrs. Hartman, Sundström, and Champion agreed in all their results within the limits of experimental error, and the outcome of their investigations was the publication by the author of a short paper on the thermo-chemistry of iron and steel.* The results given below have been carefully verified, and will, I think, stand critical examination without being found far from the truth.

When iron is dissolved in ammonium or potassium cupric chloride in a calorimeter, solution is complete and the temperature becomes constant only when all the copper is in solution either as cuprous or cupric chloride; the solution of iron in cupric chloride must therefore be represented by the following thermal equation:—

$$Fe + 2CuCl_2 = FeCl_2n + 2CuCl$$
$$Fe + (2 \times 62{,}710) = 99{,}950 + (2 \times 32{,}875)$$
$$\text{or } 40{,}280 \div 56 = 719{\cdot}3 \text{ calories for each one gramme of iron.}\dagger$$

In our work, the thermometric readings, carefully corrected for loss by radiation and gain by oxidation of cuprous chloride, were reduced to calories on the assumption that one gramme of annealed pure iron evolved 719·3 calories on being dissolved in ammonium or potassium cupric chloride.

In all the calculations, which depend upon the published heats of formation of cupric chloride, cuprous chloride, ferrous chloride, manganous chloride, phosphoric acid, hydrochloric acid, water and silicic acid, the figures used are those given in Thomsen's *Thermochemische Untersuchungen*, with the exception of silicic acid, in which case the value given by Osmond‡ has been adopted. In case subsequent investigations require any change in these fundamental data, our figures would have to be changed proportionately.

* *Journal of the American Chemical Society*, vol. xxii. p. 205.
† Thomsen's *Thermochemische Untersuchungen*, vol. iii. p. 507.
‡ *Comptes Rendus*, vol. cxiii. p. 475.

The heat of formation of carbide of iron was determined by operating on the pure carbide; the carbide used for the work was obtained by electrolytic solution of carefully annealed steel. It consisted of a steel-grey powder free from mechanically mixed carbon, and contained by analysis 6·64 per cent. of carbon and 93·30 per cent. of iron, thus being almost chemically pure; in all, 155 grammes of this carbide were separated in this laboratory and its properties determined. A detailed description of this carbide has been published.*

In all the calorimetric experiments the sample used was one gramme. Experiments were made to determine the solubility of pure carbide, with the following results. When pure carbide was added to a neutral solution of ammonium cupric chloride in the calorimeter, there was no appreciable action on the carbide. When added to neutral potassium cupric chloride, there was very slight action, if any, the thermometer rising 0·05° in five minutes. A similar result followed when the carbide was added to a neutral saturated solution of mercuric chloride. When, however, the ammonium cupric chloride was acidified with 0·11 per cent. of hydrochloric acid, there was marked action, but still incomplete. When the amount of free acid was increased to 0·46 per cent., solution of one gramme of carbide was complete in three minutes with an evolution of 624·1 calories. When one gramme of the carbide was added to a solution of potassium cupric chloride containing 0·84 per cent. of free hydrochloric acid, solution was complete in two minutes with an evolution of 628·9 calories. On adding one gramme of the carbide to pure water containing 0·84 per cent. of free hydrochloric acid, very little action resulted, the rise in temperature being 0·07° in ten minutes. The above results show the necessity of having some free hydrochloric acid present, but not enough to act as free acid directly on the metal, if rapid and complete solution is to be obtained. From the number of calories obtained by dissolving one gramme of the pure carbide in acidified ammonium or potassium cupric chloride, the heat of formation of the pure carbide is readily obtained. One gramme of carbide contains 0·933 gramme of iron, which would evolve $0·933 \times 719·3 = 671·1$ calories. The absorption of heat necessary for the decomposition of

* *American Chemical Journal*, vol. xviii. p. 836.

one gramme of carbide, which absorption must represent its heat of formation, would therefore be $671 \cdot 1 - 624 \cdot 1 = 47$ calories in the case of ammonium cupric chloride, or $671 \cdot 1 - 628 \cdot 9 = 42 \cdot 2$ calories in the case of potassium cupric chloride. The difference between these two determinations, $47 - 42 \cdot 2 = 4 \cdot 8$ calories, at first seems rather large, but when we consider that this difference is on a total evolution of over 600 calories, the percentage error is reduced to about 0·7 per cent. of the total, representing a rise of 0·020° in the calorimeter, and the results must be considered as fairly satisfactory. If the higher figure, 47 calories, is adopted as the heat of formation of one gramme of carbide, then the heat of formation of the gramme molecule, represented by the equation $C_n + 3\ Fe_n = (CFe_3)_n$ would be—

$$\frac{12 \times 47}{0 \cdot 0664} = n\ 8494 \text{ calories.}$$

If the heat of formation of carbide of iron amounts to but 47 calories per gramme of carbide, then the heat of solution of pure iron or steel should not be changed much by heat or mechanical treatment of the sample, unless the metallic iron undergoes an allotropic change, accompanied by large absorption or evolution of heat. To test this latter point experiments were made on the heat of solution of cold-drawn iron wire, and of the same wire annealed in a stream of hydrogen. The wire employed had the following composition:—Carbon, 0·018; manganese, 0·000; phosphorus, 0·050; sulphur, 0·013; silicon, 0·023. The wire, drawn to a diameter of 0·22 millimetre, and existing according to the allotropic theory in the beta form, had a tensile strength of 135,520 lbs. per square inch. After annealing in hydrogen, when the iron had assumed the alpha form, the tensile strength had fallen to 58,940 lbs.

On dissolving samples of one gramme each of the cold-drawn wire, the following results were obtained with ammonium cupric chloride containing 0·84 per cent. of free hydrochloric acid, 719·3 calories, with potassium cupric chloride containing the same amount of free acid, 718·6 calories with one solution, and with a solution made at another time 720·1 calories. On dissolving one-gramme samples of the wire annealed in hydrogen in potassium cupric chloride containing 0·84 per cent. of hydrochloric acid,

719·3 calories were evolved; this would indicate that the heat of solution of pure iron is very little, if any, influenced by mechanical treatment.

The next sample was a soft steel of the following composition:—Carbon, 0·09; manganese, 0·22; phosphorus, 0·016; sulphur, 0·023; silicon, 0·000. This steel was first annealed by cooling slowly from about 1000° C. Small bars about half an inch in diameter were then heated to 1000° – 1023° C. and hardened by dropping them into ice-water. The average of the results obtained by dissolving in ammonium cupric chloride containing 0·84 per cent. free hydrochloric acid gave for the annealed metal 718·8 calories, and for the metal quenched from 1000° C., 720·4 calories. On dissolving in potassium cupric chloride containing 0·84 per cent. of free hydrochloric acid, the annealed metal gave 719·9 calories, and the hardened 718·3 calories. The variation of all these figures is within the limits of experimental error. Heat treatment does not seem to have any appreciable influence upon the heat of solution of nearly pure iron.

Experiments were next made with a high carbon steel containing carbon, 1·22; manganese, 0·780; phosphorus, 0·098; sulphur, 0·068; silicon, 0·058. This steel was annealed and quenched in the same manner as the preceding sample. The number of calories obtained on dissolving one-gramme samples of this steel in neutral and acidified solutions are given in the following table:—

Solution used.	Quenched.	Annealed.	Difference.
Neutral ammonium cupric chloride	700·3	662·1	38·2
Neutral potassium cupric chloride	699·6	628·4	71·2
Acidified ammonium cupric chloride	707·1	712·3	–5·2
Acidified potassium cupric chloride	703·9	706·7	–2·8

This table brings out some interesting facts. It will be noticed that when dissolved in neutral solutions the quenched metal evolves very much more heat than the annealed, agreeing in this with the results reported by Osmond. The difference between the calories evolved by the quenched and the annealed samples is not, however, due to the absorption of heat necessary to decompose the carbide of iron, as assumed by Baron Jüptner

in his paper, but simply to incomplete solution of the carbide present in the annealed steel. That this is the case was shown by rapidly filtering the neutral solution after action was apparently over, and the calorimetric results obtained, when enough undissolved carbide was found to account for the loss in heat. While the heat of solution of the quenched samples in neutral solution is much higher than that of the annealed, it is still not quite as high as when dissolved in acidified solution. The lower heat of solution of the quenched samples as compared with that of the annealed when dissolved in acidified ammonium or potassium cupric chloride will be readily understood from the results, obtained by the author with S. C. Babcock, published in a paper entitled "Further Study on the Influence of Heat Treatment and Carbon upon the Solubility of Phosphorus in Steel." * In this paper we showed that if the percentage of carbon in steel was low (0·10 per cent.), heat treatment, annealing, or quenching from various temperatures up to 1000° C., did not greatly vary the proportion of phosphorus soluble—that is, oxidised to phosphoric acid when treated with mercuric chloride containing one per cent. of free hydrochloric acid. 83 per cent. of the phosphorus present in the annealed metal was dissolved, while 66 per cent. was the minimum amount soluble in the quenched samples. When the same specimen of steel as the high carbon steel under discussion, with 1·22 per cent. of carbon, was treated with acidified mercuric chloride, all of the phosphorus in the annealed sample was oxidised to phosphoric acid, whereas in similarly treating a sample quenched from 1023° C., 83·3 per cent. of the phosphorus remained, combined with iron as an insoluble residue. From numerous experiments in this laboratory we have every reason to believe that acidified solution of mercuric chloride and ammonium or potassium cupric chloride have practically the same solvent action on the compounds of iron. From the equation—

$$P_2 + 10CuCl_2 + 5H_2O + Aq = P_2O_5Aq + 10CuCl + 10HCl$$
$$P_2 + (10 \times 62{,}710) + (5 \times 68{,}360) = 405{,}500 + (10 \times 32{,}875) + (10 \times 39{,}315),$$

or $158{,}500 \div 62 = 2556 \cdot 5$ calories for one gramme of phosphorus oxidised to phosphoric acid,

since this steel contains 0·098 per cent. of phosphorus, [illegible]

* *Journal of the American Chemical Society*, vol. xviii. p. 7[illegible].

83·8 per cent. is insoluble in the quenched sample. The amount of insoluble phosphorus would be 0·00098 gramme × 0·838 = 0·00082 gramme, which would have evolved, had it been oxidised to phosphoric acid, 0·00082 × 2556·5 = 2·1 calories. This phosphorus must have been combined with iron which did not dissolve, thus still further diminishing the heat evolved by the quenched sample. Assuming this iron to be the minimum amount in known phosphide, Fe_3P_2, then 0·00082 gramme of phosphorus would be combined with 0·00222 gramme of iron, or sufficient to evolve 0·00222 × 719·3 = 1·6 calories, thus we see that the minimum loss of heat in the quenched sample would be at least 2·1 + 1·6 = 3·7 calories. That is, if the carbides of iron are not decomposed when this metal is heated above 800° C. before quenching, the heat evolved by the quenched sample should be at least 3·7 calories less than that evolved from the annealed specimen.

The heat of solution of a sample of No. 5 charcoal pig iron was next determined. The solvent used was ammonium cupric chloride containing 0·84 per cent. of free hydrochloric acid. The iron had the following composition:—Graphitic carbon, 1·26; combined carbon, 2·31; silicon, 0·383; phosphorus, 0·271; manganese, 0·010; and total iron, 95·766. After dissolving each sample in the calorimeter, the solution was filtered and the amount of undissolved iron and phosphorus determined. From these data the theoretical heat of solution could be calculated and compared with the results actually obtained. The first one-gramme sample of this iron on dissolving gave 697·2 calories; the insoluble residue contained 0·47 per cent. of iron and 0·126 per cent. of phosphorus. The duplicate determination gave 695·1 calories, with 0·44 per cent. of iron and 0·123 per cent. of phosphorus in the residue. The manganese and silicon are oxidised, and pass into solution as manganous chloride and silicic acid.

If the calorimetric results actually obtained from the high carbon steel and the charcoal pig iron are compared with the theoretical amount of heat, it is possible to obtain approximately the amount of heat required for the decomposition of the carbides present. From the equation—

$$Mn + 2CuCl_2 = MnCl_2 + 2CuCl$$

$$Mn + (2 \times 62{,}710) = 128{,}000 \times (2 \times 32{,}875),$$

or 68,390 ÷ 55 = 1242·3 calories for one gramme of manganese.

For each one gramme of silicon present in iron there would be evolved 2903·7 calories. This figure is taken as the result experimentally obtained, as explained in the latter part of this paper. The theoretical amount of heat evolved by one gramme of high carbon steel may be calculated as follows:—

$0{\cdot}97776 \times 719{\cdot}3 = 703{\cdot}3$ calories for the iron,
$0{\cdot}00098 \times 2556{\cdot}5 = 2{\cdot}5$ calories for the phosphorus,
$0{\cdot}0078 \times 1242{\cdot}3 = 9{\cdot}7$ calories for the manganese,
$0{\cdot}00058 \times 2903{\cdot}7 = 1{\cdot}7$ calories for the silicon,
or a total of 717·2 calories.

The duplicate determinations in the calorimeter gave 712·9 and 711·7. We thus have the differences between these latter and the theoretical amount, $717{\cdot}2 - 712{\cdot}9 = 4{\cdot}3$, in one case and $717{\cdot}2 - 711{\cdot}9 = 5{\cdot}5$ calories in the duplicates for the amount of heat required for the decomposition of the carbides present. If the 1·22 per cent. of carbon in this steel existed as a carbide $(CFe_3)_n$, it would be equivalent to $1{\cdot}22 \times 15 = 18{\cdot}3$ per cent., and if the heat of formation of one gramme of carbide is 47 calories, the decomposition of 18·3 per cent. would require an absorption of $0{\cdot}183 \times 47 = 8{\cdot}6$ calories. This is an amount somewhat larger than that found experimentally, 4·3 and 5·5, but might not be regarded as indicating anything, if it were not considered in connection with the results obtained from charcoal pig iron. The theoretical heat of solution of this latter may be calculated like that of the steel as follows from the first sample:—

$0{\cdot}95296 \times 719{\cdot}3 = 685{\cdot}5$ calories for the iron.
$0{\cdot}00145 \times 2556{\cdot}5 = 3{\cdot}7$ calories for the phosphorus.
$0{\cdot}0001 \times 1242{\cdot}3 = 0{\cdot}1$ calories for the manganese.
$0{\cdot}00383 \times 2903{\cdot}7 = 11{\cdot}4$ calories for the silicon.
Total calculated heat, 700·7 calories.

In this only $700{\cdot}7 - 697{\cdot}2 = 3{\cdot}5$ calories are absorbed in the decomposition of carbides present. The duplicate calculated in the same way showed—

$0{\cdot}95326 \times 719{\cdot}3 = 685{\cdot}7$ calories for the iron.
$0{\cdot}00148 \times 2556{\cdot}5 = 3{\cdot}8$ calories for the phosphorus.
$0{\cdot}0001 \times 1242{\cdot}3 = 0{\cdot}1$ calories for the manganese.
$0{\cdot}00383 \times 2903{\cdot}7 = 11{\cdot}4$ calories for the silicon.
Total calculated heat, 701·0 calories.

This would give $701{\cdot}0 - 695{\cdot}1 = 5{\cdot}9$ calories for the decomposition of the carbide. This pig iron, however, contains 2·31 per cent. of combined carbon, equivalent to $2{\cdot}31 \times 15 = 34{\cdot}65$ per cent. of carbide. If all of this carbide had the same heat of formation as the pure carbide, obtained from the pearlite of annealed steel, its decomposition would require $0{\cdot}3465 \times 47 = 16{\cdot}3$ calories. This latter figure is so much higher than the absorption experimentally obtained for 3·5 and 5·9, averaging 4·7 calories, as to be outside of the limit of experimental error; it would indicate that the heat of formation of the free cementite is much lower than that of pearlite carbide.

If we calculate the micrographic composition of the high carbon steel and the charcoal pig iron, following Sauveur's formula as quoted by Baron Jüptner, the amount of pearlite carbide and of free cementite in the two samples can be approximately determined; and assuming the pearlite carbide requires 47 calories for the decomposition of one gramme, the amount required for the cementite can be found. Considering first the high carbon steel, 1·22 per cent. of carbon would be equivalent to $1{\cdot}22 \times 15 = 18{\cdot}3$ per cent. of carbides; the free iron equals $100 - 18{\cdot}3 = 81{\cdot}7$; pearlite equals $\frac{100}{88} \times 81{\cdot}7 = 92{\cdot}8$; cementite equals $100 - 92{\cdot}8 = 7{\cdot}2$ per cent.; pearlite carbide equals $18{\cdot}3 - 7{\cdot}2 = 11{\cdot}1$ per cent. The 11·1 per cent. of pearlite carbide would require for its decomposition $0{\cdot}111 \times 47 = 5{\cdot}2$ calories, that is, no heat was required for the decomposition of the 7·2 per cent. of cementite.

In a similar way the amount of pearlite carbide and of cementite in the charcoal pig iron may be determined. Before determining the amount of free iron, however, we must make allowance for the iron combined with the silicon and the phosphorus, and for the graphitic carbon. The silicon would be equivalent to 2·68 per cent. of the silicide, and the phosphorus to 0·95 per cent. of the phosphide. Thus in calculating the micrographic composition we have the sum of the pearlite and the cementite equal to $100 - 4{\cdot}89 = 95{\cdot}11$ per cent.; the 2·31 per cent. of combined carbon would be equivalent to $2{\cdot}31 \times 15 = 34{\cdot}65$ per cent. of carbides. The free iron is $95{\cdot}11 - 34{\cdot}65 = 60{\cdot}46$ per cent.; pearlite equals $\frac{100}{88} \times 60{\cdot}46 = 68{\cdot}70$; cementite

equals $95{\cdot}11 - 68{\cdot}70 = 26{\cdot}41$ per cent.; pearlite carbide equals $34{\cdot}65 - 26{\cdot}41 = 8{\cdot}24$ per cent. If, as in the previous case, the pearlite carbide has a heat of formation of 47 calories per gramme, then the heat required for the decomposition of 8·24 per cent. would be $0{\cdot}0824 \times 47 = 3{\cdot}9$ calories. The average absorption of heat found was 4·7 calories. Thus again it is seen that very little if any heat is required for the decomposition of the 26·41 per cent. of cementite. While the above evidence is not sufficient to be conclusive, it would point very strongly to the probability that free cementite is not a definite crystallised carbide of iron, but a solid solution of carbon in iron. Further evidence pointing toward the same conclusion that cementite is not a definite carbide, but a solid solution of carbon in iron, may be found from a study of the unsaturated hydrocarbons when the metal is dissolved in hydrochloric acid. The results which have been obtained in this laboratory are not as yet sufficiently conclusive to warrant publication.

If we examine a few of the results quoted by Baron Jüptner, we shall find some apparent inconsistencies that are hard to understand on any hypothesis other than that the results obtained by Osmond do not show the true heat of solution owing to the fact that he employed neutral instead of acidified solution of ammonium cupric chloride in his calorimeter. According to the allotropic theory, beta or gamma iron evolves more heat on solution than the same weight of iron in the alpha condition. Also the allotropic theory assumes decomposition of the carbides at the critical points into dissolved carbon, while the iron is transformed from the alpha into the beta or the gamma condition, according to the temperature to which the metal is heated before quenching. Again, in the allotropic theory the function of the carbon is to retard the passage of the gamma or beta iron into the alpha form, thus inducing the hardness of the metal on quenching. In considering sample No. 3, a steel containing 1·17 per cent. of carbon, Baron Jüptner calculates that the theoretical heat of solution, considering the separate elements of the steel, would be 671·5 calories, if no heat were required for the decomposition of any of the compounds present. In his calculations he has assumed the heat of solution of one gramme of pure, presumably alpha, iron to be 667·8 calories;

the heat of solution of this steel in the annealed form he gives as 591·8, and attributes the difference between the calculated and observed figures, 671·5 − 591·8 = 79·7 calories, to the heat required for the decomposition of the carbides present. If, however, we examine the heat of solution of this same sample of steel quenched, it is hard to account for the value 641·5 calories given by Baron Jüptner. According to the allotropic theory, this quenched steel should consist of gamma iron not combined with carbon, and therefore the heat of solution of this sample should be somewhat higher than the amount calculated from the free elements, instead of which it is 671·5 − 641·5 = 30 calories less than the calculated amount. This absorption of 30 calories could be accounted for only on the assumption that the quenched metal still contains carbides which require the 30 calories or more for their decomposition. The same inconsistency will be noted in sample No. 4. In this case the heat of solution calculated from the elements is given by Baron Jüptner as 646·2 calories, and that found for the annealed metal 442·1 calories, showing a difference of 204·1 calories absorbed in decomposing the carbides, instead of 104·1 as calculated by Baron Jüptner from the same figures. This latter error of 100 calories is involved in all of his subsequent calculations on this particular sample. This cast iron, like the No. 3 steel, if quenched, would consist, according to the allotropic theory, of gamma iron with dissolved carbon, and should have a heat of solution equal to or greater than that calculated from its constituent elements. The result reported by Baron Jüptner for the heat of solution of the quenched metal is 508·4 calories, or 646·2 − 508·4 = 137·8 calories less than the calculated amount. This latter amount, 137·8 calories, may be attributed to heat required for the decomposition of carbides still existing in the quenched metal; but from the behaviour of neutral ammonium cupric chloride toward pure carbide of iron as described in the early part of this paper, it cannot but be felt that the wide variation in the results obtained by Mr. Osmond is not due to absorption of heat for the decomposition of the compounds of iron, but was simply due to the incomplete chemical reaction in his calorimeter. If it is true that neutral ammonium cupric chloride gives incomplete solution of iron or steel in a calorimeter, the whole series of results

reported by Mr. Osmond would be without value, and theoretical deduction therefrom useless.

The heat of formation of the silicide of iron $(SiFe_3)_n$ may be calculated from some of the data used for a paper published by the author, with W. E. Hartman, on the influence of silicon on the heat of solution of coke cast iron.* The samples employed in this work varied in their silicon content from 0·89 to 13·63 per cent.; the amount of silicon in the pure silicide with the formula $(SiFe_3)_n$ being 14·46 per cent. Complete analyses of the various samples were made, and after each experiment in the calorimeter the solution was filtered, and the amount of iron and phosphorus in the undissolved residue determined: all of the manganese and silicon is oxidised to manganous chloride and silicic acid. From those data we can calculate the amount of heat due to the iron, phosphorus, and manganese dissolved, and obtain thus by difference the heat due to the oxidation of the silicon in the sample. The results of this series of experiments showed that when the amount of silicon was sufficient to set practically all the carbon free, the heat of solution increased in proportion to the amount of silicon present up to 11·79 per cent. When the silicon reached 13·63 per cent. the solvent employed, ammonium cupric chloride containing 0·84 per cent. of free hydrochloric acid, reacted so slowly as to be unsuited for calorimetric determinations.

In calculating the amount of heat evolved by the oxidation of the silicon, only those samples of iron containing more than 4 per cent. of silicon have been selected. The two reasons for this selection are, first, because this amount of silicon insures practical absence of combined carbon, and therefore eliminates any uncertainties on account of the heat of formation of the carbides; second, because the larger the percentage of the silicon, the less is experimental error multiplied in calculating the amount of heat evolved per gramme of silicon.

The first iron selected was a sample of No. 2 soft cast iron having the following composition:—Graphitic carbon, 3·037; silicon, 4·15; phosphorus, 1·174; manganese, 0·708; iron, 90·30. One gramme of this gave in the calorimeter 769·6 calories, with 2·95 per cent. of iron and 0·733 per cent. of phosphorus in the

* *Journal of the American Chemical Society*, vol. xx. p. 690.

insoluble residue. The amount of heat calculated for the iron, phosphorus, and manganese dissolved would be—

$0{\cdot}8735 \times 719{\cdot}3 = 628{\cdot}3$ calories for the iron.
$0{\cdot}00441 \times 2556{\cdot}5 = 11{\cdot}3$ calories for the phosphorus.
$0{\cdot}00708 \times 1242{\cdot}3 = 8{\cdot}8$ calories for the manganese.
Total, 648·4 calories.

Thus we find 648·4 calories due to the solution of the iron, phosphorus, and manganese, while the result obtained in the calorimeter was 769·6 calories. The difference, $769{\cdot}6 - 648{\cdot}4 = 121{\cdot}2$ calories, must have been due to the oxidation of 0·0415 gramme of silicon. This would give $121{\cdot}2 \div 0{\cdot}0415 = 2920{\cdot}5$ calories for one gramme of silicon oxidised to silicic acid.

The second sample was silver-grey cast iron—graphitic carbon, 2·922; silicon, 4·69; phosphorus, 1·375; manganese, 0·972; iron, 89·20. One gramme dissolved gave 765·6 calories with 3·070 per cent. of iron and 0·821 per cent. of phosphorus in the insoluble residue. The theoretical heat for the iron, phosphorus, and manganese dissolved would be—

$0{\cdot}8613 \times 719{\cdot}3 = 619{\cdot}5$ calories for the iron.
$0{\cdot}00554 \times 2556{\cdot}5 = 14{\cdot}2$ calories for the phosphorus.
$0{\cdot}00972 \times 1242{\cdot}3 = 12{\cdot}1$ calories for the manganese.
Total, 645·8 calories.

We thus have the difference between the observed result and the amount calculated for the iron, phosphorus, and manganese, $765{\cdot}6 - 645{\cdot}8 = 119{\cdot}8$ calories due to the oxidation of 0·0469 gramme of silicon. This would give $119{\cdot}8 \div 0{\cdot}0469 = 2554{\cdot}3$ calories for one gramme of silicon oxidised.

The third sample was silver-grey cast iron—silicon, 6·16; phosphorus, 1·424; manganese, 1·052; iron, 88·30. One gramme dissolved gave 820·4 calories with 3·56 per cent. of iron and 0·808 per cent. of phosphorus in the residue. The theoretical heat for the dissolved iron, phosphorus, and manganese would be—

$0{\cdot}8474 \times 719{\cdot}3 = 609{\cdot}5$ calories for the iron.
$0{\cdot}00616 \times 2556{\cdot}5 = 15{\cdot}7$ calories for the phosphorus.
$0{\cdot}01052 \times 1242{\cdot}3 = 13{\cdot}1$ calories for the manganese.
Total, 638·3 calories.

Thus we have the difference between the observed result and the amount calculated from the iron, phosphorus, and manganese

dissolved 820·4 − 638·3 = 182·1 calories, due to the oxidation of 0·0616 gramme of silicon. This would give 182·1 ÷ 0·0616 = 2956·2 calories for one gramme of silicon oxidised.

The fourth sample was a ferro-silicon containing silicon, 11·79; phosphorus, 0·019; iron, 86·70. One gramme dissolved gave 982·3 calories with 2·35 per cent. of iron and 0·010 per cent. of phosphorus in the insoluble residue. The theoretical heat for the dissolved iron and phosphorus would be—

$$0.8438 \times 719.3 = 606.7 \text{ calories for the iron.}$$
$$0.00010 \times 2556.5 = 0.3 \text{ calories for the phosphorus.}$$
$$\text{Total, } 607.0 \text{ calories.}$$

Thus we have the difference between the observed result and the amount calculated from the iron and phosphorus dissolved 982·3 − 607·0 = 375·3 calories, due to the oxidation of 0·1179 gramme of silicon. This would give 375·3 ÷ 0·1179 = 3183·2 calories for one gramme of silicon oxidised.

Since there exists no ground for rejecting the result obtained in the second sample, although it is somewhat lower than the others, the average of the results, 2920·5, 2554·3, 2956·2, and 3183·2 may be taken, which gives 2903·7 calories as the heat evolved by the oxidation of one gramme of silicon to silicic acid when the silicon is combined with iron. If we adopt the figure 207,400 as the heat of formation of hydrated silicic acid given by Mr. Osmond,* the amount of heat which would be evolved by the solution of free silicon in acidified ammonium cupric chloride can be calculated from the following equation:—

$$Si + 4CuCl_2 + 2H_2O + Aq = SiO_2Aq + 4CuCl + 4HCl$$
$$Si + (4 \times 62{,}710) + (2 \times 68{,}360) = 207{,}400 + (4 \times 32{,}875) + (4 \times 39{,}315)$$
or $108{,}600 \div 28.4 = 3824$ calories for the oxidation of one gramme of free silicon to silicic acid.

Since we have seen that one gramme of silicon if combined with iron evolves but 2903·7 calories, then the difference, 3824 − 2903·7 = 920·3, would represent the heat absorbed in decomposing enough silicide to contain one gramme of silicon. The heat of formation of the gramme molecule therefore, represented by the equation $Si + Fe_3 = SiFe_3$, would be 28·4 × 920·3 = 26,136·5

* *Comptes Rendus de l'Académie des Sciences*, vol. cxiii. p. 475.

calories. The heat of formation of one gramme of silicide of i $(SiFe_3)_n$ would be $920{\cdot}3 \times 0{\cdot}1446 = 133{\cdot}1$ calories.

The values obtained for the heat of formation of carbide a silicide of iron explain readily why silicon displaces carbon fi its compounds with iron, causing the carbon to assume the : or graphitic form; for the reaction $CFe_3 + Si = SiFe_3 + C$ wo evolve $26136{\cdot}5 - 8494 = 17642{\cdot}5$ calories.

IRON AND STEEL FROM THE POINT OF VIEW OF THE "PHASE-DOCTRINE."

By Baron HANNS JÜPTNER VON JONSTORFF (Donawitz, Austria).

The several, and to some extent self-contradictory, theories elicited by Professor Bakhuis-Roozeboom* in his epoch-making publication of last autumn have induced me to re-examine the original treatises of which he made use in support of his views. My object in so doing is to aid, if possible, in establishing a definite basis for future experimental research, and it is my intention now to deal principally with the state of equilibrium between martensite and graphite.

The following table shows the results of Mannesmann's cementation experiments, after making due allowance for the correction of temperatures. It should be mentioned that in calculating the latter, precisely the same method has been followed as that employed by H. Le Chatelier † in dealing with the temperatures of the fusion of substances as given by Mannesmann :—

Percentage of Carbon.	Temperature of Saturation.	Percentage of Carbon.	Temperature of Saturation.
	° C.		° C.
0·35	400	3·5	1060
0·5	760	4·0	1070
1·0	890	4·5	1080
1·5	960	5·0	1085
2·0	990	5·5	1090
2·5	1020	6·0	1095
3·0	1040	6·5	1100

On the other hand, Mannesmann states that iron, when at the melting-point of copper, say at about 1050° C., can absorb only 1·8 per cent. of carbon, a statement strikingly at variance with the data given in the table. Osmond,‡ moreover, suggests

* *Journal of the Iron and Steel Institute*, 1900, No. II. p. 311.

† *Bulletin de la Société d'Encouragement*, 1900, p. 661.

‡ *Ibid.*, p. 652.

with good reason that Mannesmann very possibly never reached the saturation point.

In some further experiments on the cementation of iron carried out by Royston,* the following values representing the rate of absorption of carbon were obtained:—

At 620° C.	0·0 per cent. carbon.
„ 720° C.	0·85 „ „
„ 1030° C.	1·50 „ „

But unfortunately these results can only be regarded as dubious when they are contrasted with the experiments of Mannesmann, which show that iron could take up 2·75 per cent. carbon at a temperature of 1030° C.

Royston next heated a sample of white iron containing 3·85 per cent. carbon to various degrees of temperature, allowing it to cool gradually. The iron, when analysed, was found to contain—

	Combined Carbon. Per Cent.	Graphitic Carbon. Per Cent.
At 670° C.	1·10	2·75
„ 720° C.	1·20	2·65
„ 740° C.	3·05	0·80

Thus it is seen that the percentage of carbon which remained in the combined state here is much in excess of that obtained in his former series of experiments, though this difference is probably due to the incomplete decomposition of the carbide at the different temperatures.

Continuing his experiments, Royston next rapidly heated white iron containing 3·85 per cent. carbon to 1030° C., and allowed it to cool gradually; a second sample of the same iron was similarly heated to 1030° C. and suddenly quenched in water. He obtained the following results:—

	Combined Carbon. Per Cent.	Graphitic Carbon. Per Cent.
After gradual cooling	1·50	2·30
After quenching	1·50	2·35

In these experiments it is remarkable that the proportion of combined carbon in each case is exactly equal. The second experiment might have assisted in throwing some light on the

* *Journal of the Iron and Steel Institute*, 1897, No. I. p. 166.

doubtful conditions of equilibrium if it could have been shown that a complete dissociation of the carbide had taken place.

Turning now to the experiments of Saniter,* more important results are to be noted. He heated a piece of iron wire of very pure quality, 0·04 inch in diameter, in a porcelain tube together with charcoal. This was subjected for varying periods to a temperature of 900° C., and after being allowed to cool in the tube, a portion was removed for analysis. It was found to contain—

	Original Wire.	After 7 Hours Heating.	After 14 Hours Heating.	After 21 Hours Heating.
		Per Cent.	Per Cent.	Per Cent.
Total carbon . .	Trace	1·64	2·79	2·95
Graphitic carbon .	...	...	...	0·53
Combined carbon .	...	...	...	2·42
		Pearlite with bands of cementite, extending in all directions to the surface.		Pearlite, cementite, and graphite (the latter could not be detected under the microscope). The cementite was segregated towards the centre, none of the bands extending to the exterior; the surface of the wire was coated with graphite, which was carefully removed before analysis.

The rate at which the carbon was absorbed was as follows:—

In the first 7 hours	1·64 per cent.
,, second 7 hours	1·15 ,,
,, third 7 hours	0·16 ,,
Total . . .	2·95 ,,

from which Saniter deduced that at 2·95 per cent. the saturation point was reached.

According to Professor Arnold† the diffusion of carbon begins only at 750° C., and increases suddenly when 900° C. is reached. He states that there diffuses—

At 750° C. . . $Fe_{24}C$ (up to 0·9 per cent. carbon).
,, 900° C. . . Fe_3C (up to 2 per cent. carbon at the least).

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* *Journal of the Iron and Steel Institute*, 1897, No. II. p. 122.

† *Ibid.*, 1899, No. I. p. 101.

Following the same line of investigation, Margueritte* heated finely divided iron, which he had obtained from oxalate, for three hours consecutively in a current of carbonic oxide gas, and then found that the following quantities of carbon had been absorbed:—

	Carbon Percentage.
At dull red heat, 635° C.–694° C. (Taylor)	6·60
At bright red heat, 843° C. (Taylor)	6·55
At dark orange, 950° C. (fusing point of silver) . .	1·21

In this connection Osmond points out with reason that it cannot possibly be due to mere accident that the formation of carbide was effected in the first two instances.

It is evident, then, that, with regard to the process of cementation, results were obtained by the several investigators which, while differing in the extreme as to the carbon contents, are in striking accord in the result that the cement steel after the first heating was always found to contain carbon in the combined form alone, and it was only after the second, or at any rate after a prolonged heating, that the formation of graphite occurred. It is abundantly clear that there are thus two entirely distinct phenomena.

Particularly instructive are Saniter's experiments, which demonstrate that within fourteen hours of the commencement of the cementation process the steel contained only martensite and cementite, and that the cementite bands penetrated the entire mass as far as the surface. At the end of twenty-one hours, however, the cementite had segregated near the centre, and graphite had been formed. These successive phenomena point to the conclusion that within a temperature of about 1000° C. graphite is not the more stable form of carbon compound. This view is also strongly borne out by Osmond's† observations, which, taken in conjunction with my own views‡ on the critical points in the neighbourhood of 1000° C., would seem to furnish ample proof of the existence of the reaction assumed by Roozeboom to take place at this temperature:—

Mixed crystals + graphite = martensite + cementite.

* *Comptes Rendus*, vol. lix. p. 726.
† *Bulletin de la Société d'Encouragement*, vol. v., 1900, pp. 657, 658.
‡ *Journal of the Iron and Steel Institute*, 1900, No. I., p. 219.

It must, therefore, be assumed that the absorption of carbon by the iron at the temperature in question is accompanied by the formation of martensite—and that in the first place the state of equilibrium—

Fe + C = martensite,

though perhaps only apparent, is established.

In such cases where the martensite does not come into immediate contact with the carbon, that is to say, in the interior of the mass of iron or at such places on the surface where no charcoal actually touches, the separation of cementite may occur, and indeed must, when the point of saturation corresponding to the given temperature is reached, and thus there is reached a second state of equilibrium—

Martensite + cementite,

which not only explains the high carbon percentage which some investigators obtained, but agrees fully with the micrographic observations recorded by Saniter. Whether the carburisation under these circumstances can be continued till the state of equilibrium—

Graphite + cementite,

is reached, is open to question, but the theoretical possibility of reaching it cannot be denied. Evidence of this is also afforded by the experiments of Margueritte.* If this were possible, the corresponding equilibrium curve would be represented by a line drawn vertical to the carbon percentage line at 6·67 per cent. carbon.

In explanation of the occurrence of graphite after long heating to redness or prolonged cementation, it will be necessary to consider Saniter's experiments on the behaviour of the carbide of iron at higher temperatures. Briefly the results were as follows:—

* It is, however, quite possible that the high degree of carburisation obtained by Margueritte was mainly the result of the use of carbon monoxide, instead of carbon in a solid form.

	First Sample.		Second Sample.	
	Combined Carbon.	Graphitic Carbon.	Combined Carbon.	Graphitic Carbon.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Original carbide	6·73	0·19	6·46	0·22
After heating in nitrogen to 800° C. and gradually cooling	5·72	0·40	...	...
After heating in nitrogen to 1000° C. and gradually cooling	3·63	2·50	3·79	2·41
After heating to 1000° C. and then quenching	5·57	0·56	...	...
Fused with magnesia and allowed to cool gradually	...	...	1·22	3·05

It will be noticed that with the increase of temperature the carbide dissociates; this is shown too in Margueritte's experiments, where the diminution in the amount of carbon absorbed is apparent as the temperature increased; it is also evident that the dissociation of the cementite must commence when martensite is present, probably according to the equation—

Cementite = martensite + graphite.

This theory still leaves much to be accounted for; for instance, the formation of graphite in conjunction with ferrite in the Brustlein steel, described by Osmond,* and further investigation of this is necessary before any definite conclusion can be drawn.

Above the temperature under consideration, of about 1000° C., at which the transformation of graphite + martensite into cementite occurs, there can exist no doubt that graphite has a greater stability than cementite. The formation of graphite in slowly cooled iron seems to confirm this, as well as the dissociation of the cementite. But if this is so, then the line *a* E, which, according to Roozeboom's hypothesis, indicates the separating out of the graphite at the corresponding temperature, must cut the cementite curve at the point E.

Of great interest are Le Chatelier's observations on the expansion of steel and the formation of troostite. The sudden contrac-

* In regard to this, particular attention should be directed to the influence of other elements.

tion attending the transformation of pearlite into troostite would account for the diminution of volume which so frequently occurs during the formation of solutions. In like manner it would seem reasonable to assume that the equally sudden expansion which accompanies the transformation of troostite into martensite may be accounted for by regarding troostite as a solution of carbide of iron, which is decomposed or becomes depolymerised on its transition into the martensite form; the expansion being due to the increase in the number of existing molecules.

A WATER-COOLED BLAST-FURNACE BOSH.

BY AXEL SAHLIN (MILLOM, CUMBERLAND).

THE problem of maintaining the bosh and hearth lines of a blast-furnace, subjected, as they are, to the combined destructive influences of high temperature and incessant abrasion by the descending materials, is one which has confronted all blast-furnace managers, and to the solution of which most of them have given much study and experiment. The result of these experiments and of the experience gained are the various forms of water-cooling devices, which now are in use for protecting the walls of the lower part of the blast-furnace.

In England, where, in most cases, small outputs satisfy both directors and management, the problem has hitherto been less difficult than in America. The custom in the former country has generally been simply to increase the thickness of the brick walls, on the principle, evidently, that it takes a longer time for a furnace to cut through a 6-foot wall, than to ruin one 2-foot thick. When a furnace has been built from the beginning with a small hearth and with a bosh wide out of all proportion to the hearth and to the quantity of blast available, the shape of the furnace is of little importance. A few feet more or less on the furnace bosh has not made much difference, as long as the furnace never is made "to work all over." With these wide furnaces and slack blast, you are practically blowing into an ore pile.

The brickwork surrounding this pile of ore is taxed but little and lasts indefinitely. Under these conditions, however, the control, which the manager should have over the working of his furnace, is to a great extent lost.

When, on the other hand, as in America, keen competition and high cost of individual labour make large output, rapid driving, and close control of the furnace working imperative; when, therefore, the hearth must be enlarged, the bosh made to correspond, and the pressure and quantity of blast increased, so

as to make the furnace evenly effective throughout; then the brick walls themselves—and not scaffolds covering them—will give the outline of the working furnace. Even the best of fire-brick unaided by outside cooling influences will then no longer resist the destroying action from within.

Amongst the means for cooling the blast-furnace bosh walls hitherto in use are:—

Open cast iron or bronze boxes filled with water.

Closed bronze boxes under water pressure.

Copper pipes built into the brickwork.

Brick-lined plate shells sprayed on the outside.

Similar plate shells surrounded by successive rows of circular horizontal water pockets.

These are old and well-tried devices, each having its distinctive advantages and advocates, and also its drawbacks.

The open cast-iron and bronze boxes, with their slow circulation, are liable to burn through or crack from unequal expansion, in which case the cooling water must be turned off, and the boxes become worse than useless.

The closed bronze boxes under pressure are very expensive in first outlay and require a large quantity of clean water under a considerable head. As the side which they present to the fire is comparatively narrow, and the distance between the rows comparatively large, they tend to the formation of horizontal ridges on the bosh walls opposite each row of plates. If a leak should occur in a box, it is difficult promptly to locate, and as the water must circulate through the boxes under high pressure, great damage may be caused to the furnace before the defective box is discovered and the water turned off.

Water-pipes and coils built into the brickwork are often broken by the expansion or settling of the brickwork. They are periodically getting clogged, are difficult to exchange, and complicated to control.

The shell with outside spraying is sloppy, and, on account of the slope of the bosh, very difficult to cool uniformly all over.

Plate shells with horizontal circular pockets are not satisfactory, as the deep pockets, in spite of every attention, will get filled up with mud and incrustations, preventing the contact of the [illegible] water with the shell, which, in consequence, soon become

Perhaps the most general criticism, which can be passed upon all the arrangements above described, is, that the cooling effect carried to the bosh walls is not sufficiently uniform at all points, the result being a tendency for the inside of the bosh walls to become ridged and uneven. At the same time, all of them have many good points, and to-day successfully hold many a furnace lining to its intended shape under severe duty.

What is wanted is a device that will meet the following conditions. It must—

(1) Maintain the furnace bosh at its proper diameter and slope during the entire campaign of the furnace.

(2) Be reasonable as to cost.

(3) Consume only a moderate quantity of cooling water.

(4) Be accessible for cleaning while the furnace is running.

(5) Supply mechanical strength and stability to the structure of the bosh.

(6) Permit of easy regulation of the amount of cooling at different levels, as the zone of fusion is raised or lowered in the furnace.

(7) Ensure that no water can leak into the furnace.

To meet these conditions, the author has designed and successfully employed at the Millom Works bosh casings, which he has reason to believe are original.

The device consists of a plate shell in the shape of an inverted frustum. To the outside of this shell are riveted open troughs spirally wound around the plate from the top of the bosh to the circular discharge trough, which forms the base of the frustum. The bosh jacket is built of $\frac{1}{2}$-inch steel plates with flush joints, butt strapped on the inside, and double riveted. The jacket is supported on the furnace walls by aid of a circular rim of a 4-inch by 4-inch by $\frac{5}{8}$-inch angle bar. At the bottom it is riveted to a circular steel water-trough. The spiral troughs are two in number; they are made up of $1\frac{1}{2}$-inch by $1\frac{1}{2}$-inch steel bar, and an 8-inch by $\frac{1}{2}$-inch steel plate, forming respectively the bottom and front of the troughs, which are pitched at an incline of about $\frac{1}{2}$ inch to the foot. The vertical distance from bottom to bottom of the spirals is 14 inches (Plate XVI.).

If water is admitted to the top ends of the spirals, the bosh will, therefore, at once be surrounded by parallel bands of flow-

ing water about 3 inches wide, spaced 11 inches apart. The inside of the steel jacket is lined with 9 inches of the very best firebrick obtainable, carefully fitted. Gradually this brick lining will disappear, and be replaced by a layer of the characteristic silico-graphitic mass, which the furnace deposits, wherever the fire of the interior is met by an energetic external cooling action.

The experience which led to the design and adoption of this arrangement may be worth recording.

In 1883 the author designed a small spiegel furnace in Western Pennsylvania. It was built 66 feet high, 12 feet wide in the bosh, with a hearth of 6 feet 6 inches diameter. The furnace was constructed inside of an old-fashioned square stone stack. Space was most limited, and cooling difficult to obtain. To arrange for this, a plate shell lined with 9 inches of firebrick was used for the bosh, water being sprayed on the outside of the shell. The furnace ran for over two years, making an increased output of spiegel iron; it was then blown out for financial reasons. The bosh gave no trouble whatever. Red hot spots occasionally appeared on the plate shell, owing to unequal and defective cooling, and the cutting away of the lining, but, as soon as a spray was directed against such a point, the trouble disappeared.

Later, in 1890, the author was entrusted with the construction of another furnace in Pennsylvania, intended for the production of basic iron. It was built 75 feet high, 18 feet 6 inches in the bosh, and 9 feet 6 inches in the hearth. A plate bosh jacket was again employed, this time backed by a brick wall 13½ inches thick. The furnace was successfully blown in, and produced from 900 to 1000 tons of basic iron per week. After about half a year, it was, through an error of the superintendent, limed up almost past redemption. Cold blast and excessive temperatures, sufficient to fuse the brick in the stoves, were alternately employed: large charges of dynamite were exploded inside of the furnace below the now perfectly-formed, dome-like scaffold. Finally the scaffold was melted down with oil blow-pipes, and the furnace re-started. It then ran for a few months, when it again was scaffolded above the bosh and chilled. After the furnace had been dug out, the author was called on to examine and report on the lining. The lower portion of the barrel, where the scaffold

had been formed, was somewhat worn, and the hearth, the walls of which originally were 40 inches thick, was considerably cut away; but the bosh wall presented a smooth, regular, and glazed surface from top to bottom. Directly in front of the spraying pipes the lining was somewhat thicker, but the average depth of the coating was proved to be from 7 to 9 inches. Holes were cut through it in two places, but no vestige of brick was found, the mass being, however, so hard as almost to defy the chisel. It was, therefore, reported that the bosh lining was good, and, after some smaller repairs to the hearth, the furnace was again started. It now ran for more than two years, and no trouble was ever experienced with the bosh walls.

It has, therefore, been demonstrated that a properly cooled iron plate exerts a protective influence on a brick wall built up against the same to a depth of from 7 to 9 inches, and also that the brick is gradually worn away or decomposed, a graphitic mass of about the same thickness taking its place on the inside of the plate.

From an economical point of view, the "Sahlin bosh" compares favourably with a bosh cooled by means of bronze plates as will be seen by the following comparison of approximately estimated costs of a furnace bosh 14 feet high, 19 feet inside diameter at the top, and 11 feet diameter at the base, viz. :—

1*st.*—*Sahlin's Bosh.*

One bosh jacket with discharge trough complete, erected, including all expenses	£500
8000 bricks at £5 per thousand	40
Setting same at 30s. per thousand (plain wall)	12
Four 1¼-inch water pipes at £2 each	8
Total cost of bosh about	£560

2*nd.*—*Bosh cooled with Bronze Boxes.*

96 bronze boxes (8 rows)	£650
7 circular steel hoops	93
30,000 9-inch bricks at £5 per thousand	150
Setting ,, ,, at 50s. per thousand (arches)	75
One circular discharge trough 12 by 18 inches	150
Twelve 1¼-inch supply pipes with cocks at £3 each	36
72 connecting pipes at 10s. each	36
12 discharge pipes at 20s. each	12
Total, about	£1202

These estimates are based on prices ruling in December 1900.

PLATE XVI.

Ballantyne, Hanson & Cº Edinburgh & London.

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'he "Sahlin bosh" is practically indestructible, its life being long as that of the $\frac{1}{2}$-inch steel plate. The thinness of the brickwork or deposit prevents the disruption of the jacket, so common in furnaces with thick brick walls. As the conductivity for heat of a plate is considered inversely proportional to its thickness, it is an open question whether a $\frac{3}{8}$-inch, or even a $\frac{5}{16}$-inch, shell would not give a better result than the $\frac{1}{2}$-inch plate, which has been used for the first furnaces at Millom.

The spiral troughs can be cleaned or scraped out at any time without shutting off the water. If required, a fresh supply of cold water may be added at any point of the descent. Two streams of water admitted near the top of the troughs will uniformly cool the entire surface of the bosh.

Everywhere in Great Britain the blast-furnaces are built on low columns. Their plate shells are of enormous diameters, sometimes as much as 32 to 34 feet. In remodelling these furnaces, it will be found difficult to arrange for cooling space and air circulation around the bosh. The "Sahlin bosh" will provide this, as it can be placed inside of the old shell at any height above the lintel plates supported by the columns. The angular space between the out wall and the bosh plate would not give access to a number of rows of cooling plates, but, however narrow the space, the spiral troughs can be reached and kept clean; while, for air circulation, a few openings cut through the brickwork and the outside furnace casing, close under the upper edge of the bosh, will suffice. It is, therefore, hoped that the new bosh arrangement will aid in the economical modernising of our old furnaces.

CORRESPONDENCE.

Mr. Joseph Cooper stated that he had read Mr. Sahlin's paper on a "Water-Cooled Blast-Furnace Bosh" with interest, but wished to point out that his device was not novel nor original. Spiegeleisen and ferro-manganese were first made in this (or any other country) from manganiferous ores in a blast-furnace at the Landore-Siemens Steelworks under the management of Mr. James Riley, to whom he (the writer) then acted as assistant. In the year 1875 Mr. Riley designed a small furnace which was erected for making ferro-manganese. All the lining below the bosh was formed of carbon about 2½ inches thick in a steel-plated shell, and on the outer side of the shell horizontal V-shaped channels were formed at intervals of about 9 or 10 inches for outside water cooling. Notches were cut all round in each channel, so that the water trickled down from one channel to the next below, and so completely cooled all the casing down to the bottom of the furnace, and was from there conducted to a drain. This acted well, and continued in use until it was necessary to replace the carbon lining some months afterwards, when it was again put to work. Hot places in the casing occasionally appeared, which were cooled down by the aid of a hose-pipe.

Mr. Sahlin replied to Mr. Joseph Cooper's statement, that he had previously employed a bosh casing similar to that described by the writer of the paper, by pointing out that Mr. Cooper evidently had never grasped the novel point and great advantage of the arrangement of Sahlin's water-cooled bosh. This consisted of the continuous spiral troughs being inclined at such an angle as to make the water flow rapidly through them. Neither Mr. Cooper nor Mr. Riley were the first to use horizontal V-shaped channels around the bosh. Such an arrangement had been tried on many furnaces, and had not been found satisfactory, for the reason that the V-shaped troughs filled up with incrustations and silted matter. The spiral continuous troughs kept clean as long as the water flowed through them.

BRINELL'S METHOD OF DETERMINING HARDNESS AND OTHER PROPERTIES OF IRON AND STEEL.

BY AXEL WAHLBERG (STOCKHOLM).

IN testing materials, the determination of their relative degree of hardness presents constantly recurring difficulties, both of a theoretical and of a practical nature, and there is hardly any exaggeration in the general assertion that all methods hitherto proposed, based on theory, have proved to be almost useless for practical purposes, while the methods evolved by experience, though more useful, or at all events practicable, are based on a more or less defective theoretical foundation.

Although this may be due to various causes, or to a combination of circumstances, it will be sufficient here to call to mind the need, in the first place, for a common understanding of the term "hardness," the meaning of which is by no means universally agreed upon; while, with regard to other terms, such as ultimate stress, elongation, &c., there exists no such difficulty, since these terms convey an absolute meaning. The term hardness, on the contrary, merely expresses a certain relative condition, like other expressions such as heat and cold.

Presumably, the most generally accepted sense of the term "hardness" ought to be the *resistance offered by a solid substance to the entrance of another substance into it.*

The various methods hitherto employed to ascertain the hardness of solid substances have been classified by Professor A. Martens * into two main divisions—

1. Hardness determined by forcing into one material another substance of superior hardness.

2. Hardness determined from the tensile properties of the material.

To these there might be added a third division, viz. :—

3. Hardness determined by testing a material with itself (Foeppl's method).

* *Handbuch der Materialienkunde für den Maschinenbau.*

Without further describing one or other of the methods hitherto practised, a few remarks may be permitted with regard to the general principles involved.

Any method purporting to determine the hardness of a material by testing its tensile properties must of necessity be based on the presupposition of a constant relation existing between the property of hardness and such tensile properties. It is presumably true that such a relation exists to a certain limited extent; but outside these limits, which in the case of metals are determined by their chemical composition, mechanical treatment, &c., any method of this kind will prove to be quite useless. Moreover, it is essential that the test specimens should be of a certain shape and size, a condition often difficult or even impossible to comply with.

Further, in the methods hitherto employed for testing hardness, which fall mostly within the first-mentioned category, there exists a weak point common to all, viz., the want of a standard testing substance. When the hardness of different materials, or of the same material under different conditions, is to be tested by means of another material of greater hardness being forced into them, this latter must possess a certain constant character and be incapable of changing its form, otherwise there is no possibility of obtaining trustworthy results for the purpose of comparison. And it must be admitted that though these conditions can be approximated to sufficiently for practical purposes in any one testing laboratory, yet if tests by this method were carried out in different places by different persons, the results so obtained would scarcely admit of any kind of direct comparison. This is unquestionably a somewhat serious drawback. Another drawback also common to all these methods is the difficulty of establishing a perfectly uniform and constant mode of procedure so as to render the test-results as far as possible independent of individual bias.

In order to avoid difficulties of the above nature, Heinrich Herz, a German scientist, now deceased, conceived the idea of determining hardness by testing the material with itself, but he never worked it out any further. The idea was again taken up by Professor Foeppl of Munich, who has taken great pains in realising it. The proceeding may be described as follows:—

Two flat specimens, 15 millimetres by 25 millimetres, are cut out of the material, and to one of the large surfaces of either is given a semi-cylindrical shape, with 20 millimetres radius, the cylindrical surface thus obtained being carefully polished. The two specimens thus prepared are placed crosswise, the one upon the other, and then pressed together in a testing machine. Until the elastic limit be obtained no permanent indentation is caused, but beyond that limit there will be two lasting marks obtained in the shape of small round spots, the size of which is inversely proportional to the hardness, the loading being supposed to have been constant. If the two specimens are of the same material, the size is directly proportionate to the pressure employed. From a theoretical point of view this method might be considered as satisfactorily fulfilling most of the conditions required, but, unfortunately, it is of little use for practical purposes except in a few cases. This is partly on account of the difficulty of preparing the test specimens without more or less alteration to that part of the specimen where the test is to take place, through removal of the surface, and in consequence a true indication of the relative hardness of the material is not afforded. Partly, also, because those tests are always most difficult of execution on account of the indispensable condition of making the pressure during the whole operation exactly at right angles to the tangent of the curves at the point of contact, for which purpose a special type of testing machine would be required.

I.—Brinell's Method.

Among the several modes and methods hitherto known and made use of there is hardly one that might be termed satisfactory, and the invention of one that would be quite suitable for practical use has been until now a much-felt want in carrying out metallurgical investigations, and more especially in those connected with the iron and steel industry.

One of those who have devoted themselves with the greatest energy to the solution of this problem is Mr. J. A. Brinell, chief technical manager of the Fagersta iron and steel works in Westmanland, Sweden. In the course of his untiring studies and investigations of the properties of iron and steel, his attention

was first directed to this particular subject through the want of some ready and at the same time easy and trustworthy means of controlling what are called the "forging tests," commonly resorted to in practical working, and of ascertaining, in fact, more especially the relative hardness of materials. Since the method invented by Foeppl, remarkable in other respects, proved to be quite unfit for practical purposes, Mr. Brinell soon made up his mind as to the kind of method to be preferred, and having come to the conclusion that, in order to ascertain the hardness of a substance, some standard body was primarily needed as a testing tool or medium, he first set himself to find one which might prove to be quite suitable for the purpose. As to the best form of such a tool for making an indentation or impression, he had no doubt that a spherical body would be preferable to the conical, edge-like, or pyramidal bodies formerly used, as the former unquestionably offers a better chance of obtaining a constant and uniform result, when used at different places and on different occasions. The next point to be decided was the composition of the material, which ought necessarily to be exceptionally hard, and at the same time easy to procure, and so far as possible not liable to alterations in its mechanical properties. It then struck him that hardened steel balls, such as are used in ball bearings, might do for his purpose. These balls are always made in a most careful and rational manner, from very superior and homogeneous material, and at the same time they are accurately assorted, by picking out and discarding any which may be found to differ from the others in their degree of hardness.

The balls made use of by Brinell in his experiments were obtained from the "Deutsche Guss-stahlkugelfabrik" at Schweinfurth, and have proved to be excellent. There are, in fact, very few instances on record of their breaking or flattening even when testing thoroughly hardened tool steel of the highest percentage of carbon, or on thorough white cast iron, containing 5 per cent. of manganese.

According to Brinell, no method purporting to determine hardness is to be considered as suitable for practical use, unless fulfilling the following requirements:—

1. It must give trustworthy results.
2. It must be easy to learn and to apply.

3. There should be no necessity for costly or time-wasting mechanical treatment of the material previous to the testing.
4. The testing medium for forcing into the material to be tested should be cheap, easy to obtain, incapable of altering its shape, and of a sufficient hardness.
5. The method should admit of finished articles, as for instance armour plates, projectiles, &c., being tested without damage to the objects; and
6. The testing results should be indicative of the absolute hardness of the material tested.

The method invented by Brinell, which he hopes will prove to be, when finally worked out, quite satisfactory on all these points, consists in forcing, by means of pressure, a hardened steel ball into the material to be tested so as to cause an impression, the diameter of which is then to be measured, in order to obtain the spherical area of the concavity. The quotient resulting from dividing the maximum pressure by this area will then represent what is called by Brinell a *hardness number*, indicating, according to him, the amount of pressure (kilogrammes per square millimetre) to which the material so tested has been subjected.

With regard to the hardness number, taken in this sense, there is, however, a certain misconception likely to arise. If a test were to be conducted in a manner similar to that described above, but using, instead of a ball, a flat circular disc, supposed to be absolutely incapable of altering its shape, he would no doubt be quite right, but the case becomes quite different when the impression is made by means of a spherical body. There is then not only a certain, however slight, alteration as to the shape of the ball to be considered, but there must also be taken into account the variations occasioned by the material being to a certain extent forced upwards around the ball as the latter enters into it. But, apart from this, a more adequate expression of the superficial pressure would be obtained by dividing the pressure used by the projection of the concavity than by the area.

It is, however, not the object of this paper to investigate the subject further from this point of view—which would require more comprehensive preliminary data than are yet available—

but only to give an account of the results already obtained by Brinell from his own observations, noting his reservation as to the preliminary and somewhat desultory character of the method hitherto employed. Hence any further investigation as to its theoretical value and import would for the present be out of place, and should be postponed until the conclusion of the inquiry and experiments, which, thanks to a munificent subvention granted by the *Jernkontoret*, are now being carried out on a very extensive scale at the laboratory for testing materials of the Royal Technical High School at Stockholm.

Apart from the question whether Brinell is right or wrong in taking the term "hardness number," as he does, in a rather literal sense, there seems to be hardly any objection which can be raised against his mode of proceeding in order to arrive at his result. While dividing by the area of the concave surface instead of by its projection, the result is no doubt, to a certain extent, rendered independent of the alteration of the material as to hardness, caused by the ball being forced in. The fact is that there is noticeable an effect similar to that caused by working metals in the cold state, this effect being increased the deeper the ball is forced into the material, or, in other words, that there may be different hardness numbers obtained with the same material, according to the depth of the impression. But this inconvenience is, at least to some extent, done away with, when proceeding in the manner proposed by Brinell, because the increase of the area of the concavity is more rapid than that of its projection, and thus the variation of quotients is also less considerable than by taking the projection as the divisor. This will be shown, moreover, by some experiments to be related further on.

The tests are performed by the Brinell method in the following manner:—

Out of the material to be tested there is cut a piece of a sufficient size to obtain a flat test specimen of a rectangular shape, say, for instance, some 30 millimetres square by about 10 millimetres in thickness. The dimensions may vary down to a certain minimum. It appears from Brinell's experiments that above a minimum thickness of 2·5 millimetres the testing

results are not affected, whilst, with regard to the width, the specimen need only be wide enough to prevent any deformation of the sides, in consequence of the displacement of the material caused by the subsequent compression. A width of 30 millimetres is found to be all that is required for such a purpose. Besides, it is by no means necessary to give the specimen a strictly regular shape, it being quite enough if two of the vertical sides are about parallel to one another, and the testing surface quite smooth. Nor is there in general any need for the elaborate preparation of the surface, although this would, of course, facilitate the reading off, and render it more exact

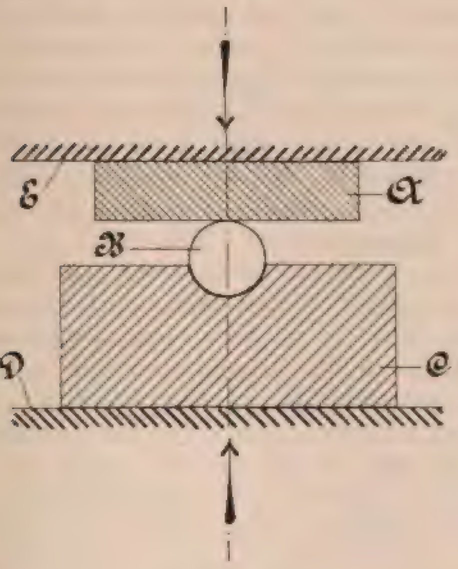


FIG. 1.

when the impression is measured. Whether the preparation of the specimens should be more or less careful and elaborate must depend on the degree of accuracy and precision required.

The arrangements necessary for carrying out the test differ according to the kind of testing machine available for the purpose. When using a compression test machine, the most convenient mode of proceeding is as shown in Fig. 1. E and

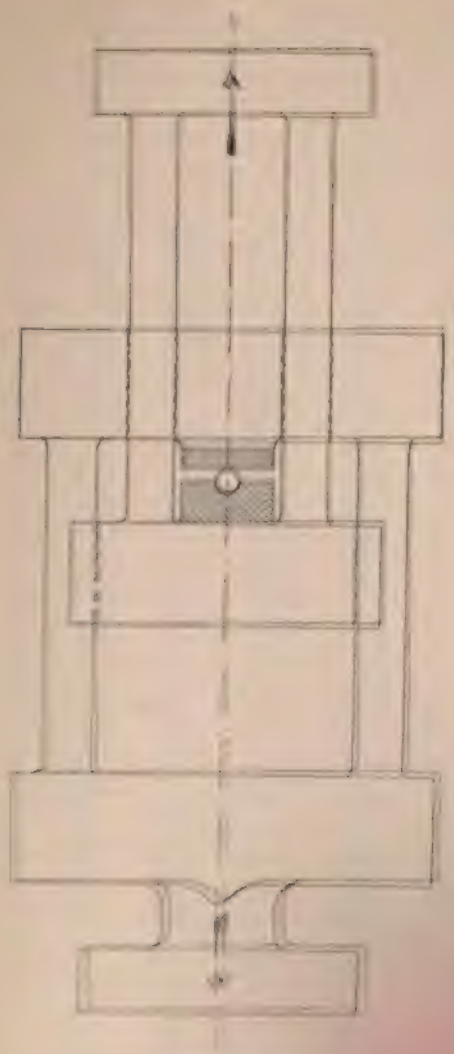
D are the compression-blocks, there being placed on the lower one a small block, C, made of steel, with a cavity in the centre of the upper surface where the ball is to rest, which part should be hardened. The test specimen is placed between the upper block and the ball, and then the pressure is applied in the ordinary manner until the required amount of loading is reached.

The influence of time and the effect on the testing results of quick or slow loading have not as yet been ascertained, but this question will be investigated during the course of experiments at present being carried out.

On removal of the load the diameter of the impression obtained is taken, preferably by means of a microscope, fixed with a millimetre scale, Vernier and cross-hair, and finally the maximum load is divided by the area of the segmental concavity. This operation is facilitated by making use of a ready-reckoning table, specially compiled for this purpose. Such a table, made up for a ball of 10 millimetres diameter, is given below in Table I. According to this, the diameter of the impression being 4·20 millimetres, with a maximum load of 3000 kilogrammes, the hardness number is 207, &c.

If there is no special compression test machine, an appliance not frequently met with in private testing laboratories, this test may be made either by means of some contrivance like that shown in Fig. 2, or by procuring some special apparatus to suit the purpose; for instance, one of the type shown in Fig. 3, which might be found rather useful where no testing machine is available. An apparatus of this kind was shown last year in the Fagersta Works department at the Paris Exhibition. It consists essentially of a system of four springs within a drum, with a screw-wheel arrangement, by means of which the loading operation is performed. The maximum pressure can then be read off on an indicator scale, empirically graduated, which is combined with the spring system.

The contrivance shown in Fig. 2 has been used by Brinell in all his experiments, by placing the apparatus in a 50-ton Mohr and Federhaff testing machine, in the same manner as an ordinary test specimen.



[illegible]

TABLE I.—*Diameter of Impression, Area of Impression, and Maximum Pressure in Kilogrammes per Square Millimetre.*

N.B.—Diameter of Ball 10 *Millimetres.*

D Diameter of Impression. mm.	A Area of Impression. mm^2.	$\frac{5000}{A}$	$\frac{3000}{A}$	$\frac{1000}{A}$	$\frac{500}{A}$	$\frac{200}{A}$
1·50	1·8095	2770	1660	551	277	111
1·55	1·8975	2640	1582	528	264	105
1·60	2·0232	2480	1487	495	248	99·0
1·65	2·1866	2290	1373	458	229	91·5
1·70	2·2871	2180	1310	437	218	87·5
1·75	2·4378	2055	1236	411	206	82·0
1·80	2·5761	1940	1164	388	194	77·5
1·85	2·7112	1848	1108	368	185	73·8
1·90	2·8620	1750	1048	350	175	69·9
1·95	3·0159	1660	995	332	166	62·2
2·00	3·1762	1577	946	316	158	63·0
2·05	3·3427	1498	898	298	150	59·8
2·10	3·5029	1430	857	286	143	57·0
2·15	3·6757	1361	817	273	136	54·0
2·20	3·8485	1304	782	261	130	52·0
2·25	4·0275	1242	744	248	124	50·0
2·30	4·2097	1189	713	238	119	48·0
2·35	4·3982	1139	683	227	114	46·0
2·40	4·5930	1090	652	218	109	44·0
2·45	4·7885	1045	627	209	105	42·0
2·50	4·9889	1000	600	200	100	40·0
2·55	5·1931	963	578	193	96	39·0
2·60	5·4036	925	555	185	93	37·0
2·65	5·6188	889	532	178	89	36·0
2·70	5·8340	855	512	171	86	34·0
2·75	6·0586	827	495	166	83	33·0
2·80	6·2832	798	477	159	80	32·0
2·85	6·5172	767	460	153	77	31·0
2·90	6·7513	741	444	148	74	30·0
2·95	6·9696	718	430	144	73	29·0
3·00	7·1880	696	418	140	70	28·0
3·05	7·4629	670	402	134	67	27·0
3·10	7·7378	645	387	129	65	26·0
3·15	8·0001	625	375	125	63	25·0
3·20	8·2624	606	364	121	61	24·0
3·25	8·5310	587	351	117	59	23·5
3·30	8·7996	569	340	114	57	23·0
3·35	9·0792	551	332	111	55	22·0
3·40	9·3588	535	321	107	54	21·4
3·45	9·6478	518	311	104	52	20·7
3·50	9·9369	502	302	101	50	20·2
3·55	10·2353	488	293	98	49	19·6
3·60	10·5338	476	286	95	48	19·0
3·65	10·8416	462	277	92	46	18·5
3·70	11·1495	448	269	90	45	18·0
3·75	11·4495	436	262	88	44	17·5
3·80	11·7496	425	255	85	43	17·0
3·85	12·0951	414	248	83	41	16·5
3·90	12·4407	402	241	81	40	16·0
3·95	12·7785	392	235	78	39	15·6
4·00	13·1162	382	228	76	38	15·2
4·05	13·4712	372	223	75	37	14·9

TABLE I.—(*continued*).

D Diameter of Impression. mm.	A Area of Impression. mm².	$\frac{5000}{A}$	$\frac{3000}{A}$	$\frac{1000}{A}$	$\frac{500}{A}$	$\frac{200}{A}$
4·10	13·8262	362	217	73	36	14·5
4·15	14·1749	353	212	71	35	14·1
4·20	14·5236	345	207	69	34·5	13·8
4·25	14·8943	336	202	67	33·6	13·4
4·30	15·2650	326	196	65	32·6	13·1
4·35	15·6451	319	192	64	32·0	12·8
4·40	16·0253	312	187	63	31·2	12·5
4·45	16·4148	304	183	61	30·4	12·2
4·50	16·8044	297	179	60	29·7	12·0
4·55	17·2065	291	174	58	29·1	11·6
4·60	17·6087	284	170	57	28·4	11·4
4·65	18·0186	278	166	56	27·8	11·1
4·70	18·4286	272	163	54	27·2	10·9
4·75	18·8527	265	159	53	26·5	10·6
4·80	19·2768	259	156	52	25·9	10·4
4·85	19·7135	254	153	51	25·4	10·1
4·90	20·1502	249	149	50	24·9	9·9
4·95	20·5978	244	146	49	24·4	9·7
5·00	21·0455	238	143	48	23·8	9·5
5·05	21·5042	233	140	46·5	23·3	9·3
5·10	21·9629	228	137	45·5	22·8	9·1
5·15	22·4357	223	134	44·5	22·3	8·9
5·20	22·9085	218	131	44	21·8	8·7
5·25	23·3939	215	128	43	21·5	8·6
5·30	23·8793	210	126	42	21·0	8·4
5·35	24·3694	206	124	41	20·6	8·2
5·40	24·8720	201	121	40	20·1	8·0
5·45	25·3778	197	118	39·5	19·7	7·9
5·50	25·8931	193	116	39	19·3	7·7
5·55	26·4114	190	114	38	19·0	7·6
5·60	26·9392	186	112	37	18·6	7·4
5·65	27·4733	182	109	36·5	18·2	7·3
5·70	28·0168	178	107	35·7	17·8	7·1
5·75	28·5634	175	105	35·0	17·5	7·0
5·80	29·1163	172	103	34·4	17·2	6·9
5·85	29·6818	169	101	33·8	16·9	6·75
5·90	30·2536	166	99	33·0	16·6	6·6
5·95	30·8316	162	97	32·5	16·2	6·5
6·00	31·4160	159	95	32·0	15·9	6·4
6·05	32·0066	156	94	31·0	15·6	6·25
6·10	32·6098	153	92	30·6	15·3	6·15
6·15	33·2130	151	90	30·0	15·1	6·0
6·20	33·8350	148	89	29·6	14·8	5·9
6·25	34·4602	145	87	29·0	15·5	5·8
6·30	35·0634	143	86	28·5	14·3	5·7
6·35	35·7325	140	84	28·0	14·0	5·6
6·40	36·3828	138	82	27·5	13·8	5·5
6·45	37·0426	135	81	27·0	13·5	5·4
6·50	37·7086	133	80	26·5	13·3	5·3
6·55	38·3872	131	79	26·0	13·1	5·2
6·60	39·0720	128	77	25·5	12·8	5·1
6·65	39·7632	126	76	25·2	12·6	5·0
6·70	40·4700	124	74	24·7	12·4	4·95
6·75	41·1832	122	73	24·4	12·2	4·87
6·80	41·9058	119	71·5	23·8	11·9	4·8
6·85	42·6409	117	70	23·5	11·7	4·7
6·90	43·3855	115	69	23·0	11·5	4·6
6·95	44·1394	113	68	23·0	11·3	4·5
7·00	44·9028	111	67	22·0	11·1	4·4

FIG. 3.

One of the first points to be settled, in order to form an opinion as to the importance and value of the Brinell ball-tests, is to determine the influence exercised on the test results, firstly, by different pressures while using balls of the same size; and secondly, by using different sized balls with a uniform pressure. In order to settle this question, Brinell carried out three series of experiments, which are described later on, the third of these being the most comprehensive.

In the following table (No. II.) will be found the chemical analysis of every description of steel material employed by Brinell in the various researches to be described, in all eleven different kinds, although there are only three of these mentioned in the series of tests next described. The respective numbers used in the following, to designate the material tested in any particular instance, refer always to corresponding numbers in this Table II., indicating the chemical composition:—

TABLE II.—*Analyses of Different Kinds of Steel.*

No.	C.	Si.	Mn.	S.	P.
1 . . .	0·10	0·007	0·10	0·020	0·020
2 . . .	0·20	0·018	0·40	0·015	0·022
3 . . .	0·25	0·30	0·41	0·012	0·028
4 . . .	0·35	0·26	0·49	0·015	0·022
5 . . .	0·45	0·27	0·45	0·018	0·028
6 . . .	0·65	0·27	0·49	0·011	0·028
6 a . . .	0·66	0·33	0·18	0·010	0·028
7 . . .	0·70	0·32	0·22	0·010	0·029
8 . . .	0·78	0·37	0·20	0·011	0·028
9 . . .	0·92	0·28	0·23	0·012	0·030
12 . . .	1·25	0·60	0·20	0·010	0·027

The researches purporting to ascertain the influence of different diameters of ball and of different pressure were made with three kinds of steel, indicated in the above table of analyses by No. 1 (very soft), No. 5 (medium hard), and No. 12 (very hard). The test results are given below in Table III.

TABLE III.—*Influence on the Hardness Result of Different Diameters of Ball and of Different Maximum of Loading.*

Diameter of Ball. Millimetres.	Maximum Loading. Kilogrammes.	Material Tested.								
		Steel No. 1.			Steel No. 5.			Steel No. 12.		
		Impression.		Hardness No.	Impression.		Hardness No.	Impression.		Hardness No.
		Max. Diam. Mm.	Area Sq. Mm.		Max. Diam. Mm.	Area Sq. Mm.		Max. Diam. Mm.	Area Sq. Mm.	
5·0	500	2·45	5·0375	99	1·80	2·6327	191	1·40	1·5706	317
	1000	3·25	9·4264	106	2·40	4·8192	207	1·90	2·9468	338
	1500	...	...	...	2·85	7·0042	214	2·30	4·4014	340
7·5	1000	3·45	9·9031	101	2·45	4·8467	206	2·05	3·3646	298
	1500	4·15	14·7592	101	3·00	7·3772	206	2·50	5·0540	300
	2000	4·60	18·5716	107	3·40	9·6015	208	2·80	6·3877	315
10·0	1500	4·20	14·5236	103	3·05	7·4629	201	2·50	4·9889	300
	2000	4·90	20·1502	99	3·50	9·9369	201	2·85	9·5172	306
	3000	5·90	30·2536	99	4·25	14·8943	201	3·45	6·6478	311
15·0	2000	5·10	21·0550	95	3·75	11·2249	178	3·05	7·3796	272
	3000	6·10	30·5458	98	4·40	15·5509	193	3·65	10·5888	284
	5000	7·85	52·2615	96	5·60	25·5506	196	4·45	15·9044	315

According to the above results it appears—

(1) That with a uniform loading, the hardness number is increased when using a ball of a smaller size. For instance, in the case of material No. 5 the uniform load of 2000 kilogrammes gives the hardness numbers 178, 201, and 208 with balls of respectively 15, 10, and 7·5 millimetres diameter, &c.

(2) That, with the same size of ball, the hardness number increases when the loading is increased. Thus, in the case of the same material No. 5 there is obtained, by means of the same ball of 5 millimetres, the hardness numbers 191, 207, and 214, with loads in the ascending rates of 500, 1000, and 1500 kilogrammes respectively.

(3) That in both cases (uniform size of ball and uniform maximum load) the divergence in the hardness result becomes more strongly accentuated when using balls of smaller size.

As already pointed out, these variations are to be attri-

to the effect of cold-working imparted to the material by forcing in the ball; and it has also been mentioned that the influence of this effect on the hardness number is to a certain extent compensated for by Brinell's system of dividing by the area, and not by the projection of the concavity. In order to further substantiate this assertion, the results as given above in Table III. have been re-calculated, but substituting the projection in place of the area as a divisor. The new results thus obtained will be found in the comparative table, as given below (Table IV.), together with the former results obtained by Brinell. The difference indicating the rates of increase in hardness shows the correctness of the statement advanced. The comparative results are also shown graphically in Fig. 4, the full lines being the average values obtained by dividing by the area, and the dotted lines those obtained by dividing by the projection.

TABLE IV.

Diameter of Ball. Millimetres.	Maximum Loading. Kilogrammes.	Hardness Numbers.											
		Steel No. 2.				Steel No. 5.				Steel No. 12.			
		Obtained when using as a divisor either the area or projection of the concavity.											
		Impression.				Impression.				Impression.			
		Area.	D.fl.	Project.	D.fl.	Area.	D.fl.	Project.	D.fl.	Area.	D.fl.	Project.	D.fl.
5	500	99		106		191		197		[illegible]		[illegible]	
	1000	106	7	121	15	207	16	221	24	[illegible]	[illegible]	[illegible]	[illegible]
	1500		...		...	214	7	234	13	340	2	361	8
7·5	1000	101		107		206		212		298		303	
	1500	101	0	111	4	206	0	212	0	300	2	306	3
	2000	107	6	120	9	208	2	220	8	313	13	323	19
10	1500	103		108		201		205		300		306	
	2000	99	4	106	2	201	0	208	3	306	6	314	8
	3000	99	0	110	4	201	0	211	3	311	5	321	[illegible]
15	2000	95		98		178		181		[illegible]		[illegible]	
	3000	98	3	103	5	193	15	197	16	284	12	287	13
	5000	96	2	103	0	196	3	203	6	315	31	321	34

Although Brinell's system seems thus to be sufficiently justified, still it must be regretted that the results of his method

depend rather on the manner in which the tests are performed, in particular cases. In order to obtain results to be compared with one another, there ought to be certain general rules established as to the mode of proceeding in testing.

With regard to the size of the ball, Brinell has found the diameter of 10 millimetres to be quite suitable. The reason

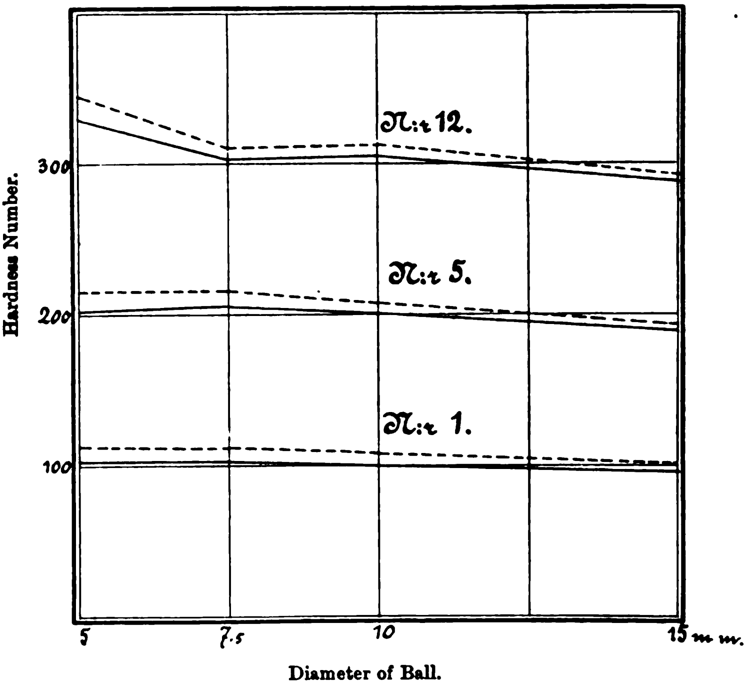


Fig. 4.

he decided on this size was that the use of a larger sized ball would necessitate the application of a greater loading stress, in order to render the outlines of the impression sufficiently sharp and visible. Moreover, larger specimens would be required in order to avoid the risk of deformation of the edges of the testing surface, while, in comparative tests at the same rate of loading, smaller sized balls would prove to be less satisfactory, on account of the faults of variation becoming more considerable in proportion to the reduction in size of ball.

There does not seem to be any reasonable objection to accepting the 10-millimetre diameter as a standard size of the ball, but, on the other hand, this would by no means remove all the difficulties in solving the problem. The above experiments show that even when using balls of a constant and uniform size, the test results will always be influenced to a certain extent by the effect of cold-working occasioned by different rates of loading. The only safe means of providing against any inconvenience of this kind, would be by always working with impressions of a constant size, because then the rate of loading required in order to produce such an impression would be directly proportional to the hardness, and the cold-working effect, to which reference has been made, being approximately constant, need not be taken into account. However, although this solution of the question may seem to be quite plausible, the difficulties of realising it prove to be still somewhat serious. To overcome these there are two different methods of procedure possible. One of these would consist in carrying out, in the case of each material, a certain number of tests, with different loading stress, until two impressions were obtained as nearly as possible of the same size, the one larger and the other smaller than the impression wanted. The value of the loading stress required in order to obtain this latter can be easily calculated by means of interpolation. The same object might also be accomplished by means of some special contrivance which would permit not only the ball and test specimen being continuously moved together, while remaining in a constant relation, but also a simultaneous increase or decrease of the loading stress taking place in such a manner that wherever the ball with the specimen be placed at a given moment, there should be a certain corresponding stress of loading, easily ascertained. A device of a special design appropriate to the purpose has also been invented by Brinell. As to the realisation of such a contrivance, there should certainly be no insuperable obstacle; but, on the other hand, it cannot but be admitted that the whole arrangement might eventually fail on account of another difficulty, viz., the non-homogeneous consistency met with more or less in most materials. This is probably the reason why

the impressions are apt rather too frequently to assume a less regular form, as shown in Fig. 5, thereby causing a certain difficulty in arriving at any exact values.

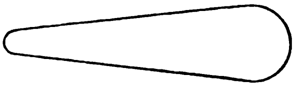


FIG. 5.

It is somewhat difficult to recommend either one or other of those modes of proceeding until the whole method of ball-testing be further investigated. The preceding remarks must be considered as being as yet only preliminary observations which may eventually fail to be borne out by future experience, although quite justifiable as matters stand at present.

No further mention need be made as to the method, its general tenor and its consequences. The results of Brinell's researches now to be described will be only occasionally commented on, with a few observations that a consideration of the matter suggests.

Owing to the abundance of matter available, and the long time it would require in order to examine it with due care and attention, it has been quite impossible to prepare for this meeting an exhaustive paper on the subject, the object of the present paper being merely to furnish a brief account of what has been actually effected up to the present time, although it is hoped that it may prove to be a sufficient basis for further investigations, and at the same time a stimulus to new and more comprehensive experiments.

II.—VARIOUS RESEARCHES BY MEANS OF BALL-TESTING.

A.—*Hardness Determined in Various Kinds of Woods, Metals, Alloys, &c.*

All these tests were made with the aid of balls of 10 millimetres diameter — the same size also having been used in some ball-tests in connection with other researches to be mentioned subsequently, but with different rates of loading stress, occasioned by the considerable difference in hardness of the various materials tested.

Thus the maximum pressure used by Brinell, when testing ron and steel, was always 3000 kilogrammes, while a stress of 00 kilogrammes was found suitable in the case of other metals nd alloys, and only 50 kilogrammes in the case of wood.

The comparative results are given in the Tables V., VI., and VII.

TABLE V.—*Hardness of Various Metals and Alloys.*

Kind of Material.	Description.	Maximum Pressure on 10 Mm. Ball.	Diameter of Impression.	Hardness Number.
		Kilos.	Mm.	
Metals	Crude copper	500	2·90	74·0
	Rolled copper	..	..	..
	Silver (fine [illegible])	..	3·25	59·0
	Antimony	..	3·35	55·0
	Gold	..	3·60	48·0
	Zinc	..	3·65	46·0
	Aluminium	..	4·00	38·0
	Tin	..	6·25	14·5
	Lead	200	6·20	5·7
Alloys	Phosphor-bronze	500	2·20	130·0
	Bell-metal	..	2·25	124·0
	Brass	..	3·15	63·0
	Phosphor-tin	..	5·45	19·7
	Rose metal	200	5·80	6·9
Antifriction metals	Alpha No. 1	500	3·75	44·0
	Svea metal No. 3	..	4·05	37·0
	Vulcan 2 A	..	..	..
	Glyco-metal	..	4·20	34·5
	Rubes No. 1	..	4·30	32·6
	Svea No. 1	..	..	..
	Salamina (Sala)	..	4·75	26·5
	Magnolia antifriction	..	4·85	25·4
	Babbitt (Axle Brand Defiance)	..	5·05	23·3

TABLE VI.—*Hardness of Swedish Charcoal Pig Iron.*

Description of Pig Iron.	Maximum Pressure on 10 mm. Ball.	Diameter of Impression.	Hardness Number.
	Kilos.	Mm.	
horough grey	3,000	4·50	179
hree-quarter grey, tested on grey part	..	4·25	202
ame specimen, tested on white part	..	3·15	375
ottled specimen, tested on all white part	..	2·90	444
ll white	..	2·85	460

TABLE VII.—*Hardness of Various Kinds of Wood.*

Kind of Wood.	Pressure on 10 mm. Ball.	Tested Longitudinally.		Tested Transversely.	
		Diameter of Impression.	Hardness Number.	Diameter of Impression.	Hardness Number.
	Kilos.	Mm.		Mm.	
Lignum vitæ (Guaiacum)	50	2·80	7·98	2·70	8·50
Ebony	„	3·50	5·02	2·50	10·00
Beech	„	4·55	2·91	3·45	5·18
Beam-tree . . .	„	4·80	2·59	3·80	4·25
Walnut	„	4·85	2·54	3·95	3·92
Maple	„	4·90	2·49	3·40	5·35
Hickory	„	4·90	2·49	3·10	6·45
Apple-tree . . .	„	4·95	2·44	3·75	4·36
Ash	„	5·00	2·38	3·50	5·02
Pear-tree	„	5·05	2·33	3·85	4·14
Oak	„	5·10	2·28	3·10	6·45
Elm	„	5·10	2·28	3·75	4·36
Hornbeam . . .	„	5·10	2·28	3·50	5·02
Mountain ash . . .	„	5·30	2·10	3·90	4·02
Birch	„	5·80	1·72	3·80	4·25
Juniper	„	5·85	1·69	3·80	4·25
Linden	„	6·45	1·35	4·55	2·91
Aspen	„	6·70	1·24	3·95	3·92
Alder	„	6·85	1·17	4·85	2·54
Larch (outside) . .	„	6·85	1·17	6·20	1·48
„ (pith) . . .	„	6·90	1·15	5·00	2·38
Fir (pith)	„	6·90	1·15	4·50	2·97
Mahogany . . .	„	7·15	1·06	4·90	2·49
White pine (pith) . .	„	7·65	0·89	4·95	2·44
Fir (outside) . . .	„	7·80	0·85	4·85	2·54
White pine (outside) .	„	8·10	0·77	4·20	3·45

B.—*Controlling the Purely Practical Tests or "Forging Tests."*

According to a custom prevailing in Sweden, as also in many other places, every charge of iron or steel is practically tested by means of a so-called forging test, as well as by means of the chemical carbon determination usually performed in Sweden by the Eggertz method, while the combustion determination is used but rarely, as for instance in doubtful cases, or even periodically for checking purposes. Although the Eggertz method should give exact and trustworthy results as to the percentage of carbon, this is far from being always the case, the irregularities that occur every now and then becoming more noteworthy with increasing quantities of extraneous matters contained in the iron, such as chromium, nickel, and manganese,

especially in cases of imperfect annealing. Unless the steel is properly and carefully annealed, the Eggertz test will prove to be almost worthless. The forging test referred to is only to be considered as a practical method of classifying the iron or steel material according to a certain scale of hardness, the graduation of which has been so made as to correspond to a certain extent in a material of ordinary composition to ascending percentages of carbon. The results obtained by means of this test will, however, be influenced not only by the percentage of carbon, but also to a considerable extent by the presence of other constituents, while at the same time the whole test depends to a somewhat considerable extent on the individual skill and judgment of the operator, although it must be confessed that the degree of skill and accuracy of judgment displayed by the Swedish forging testers is quite astonishing. As already mentioned, it was the need for rendering these testing operations as far as possible independent of any such influences of a casual and personal character, which first made Brinell think of devising some other more satisfactory and rational method.

At the Fagersta works it has become a fixed rule that every charge of open-hearth steel should be controlled, as to hardness, by means of ball-testing. The test specimens, after having been carefully annealed, are prepared just as far as needful by smoothing off one of the sides on an emery-wheel, taking care in so doing that the steel is not heated to any appreciable extent.

A scale of the ascending rates of hardness, as established by Brinell in the case of ordinary Fagersta steel, together with the corresponding carbon percentages, is given below, in Table VIII. :—

TABLE VIII.

Carbon per Cent.	Corresponding Hardness Number.
0·1	97
0·2	107
0·3	145
0·4	156
0·5	185
0·6	215
0·7	232

According to the above scale, it appears that the increase in hardness and in carbon contents does not always take place at the same rate. This is to be explained by the variations in the percentage of manganese and silicon met with in Fagersta steel of different percentages of carbon. Thus the considerable increase of hardness to be found in the case of 0·2 per cent. of carbon, as compared with 0·3 per cent., is due to the low percentage of manganese and silicon in the 0·2 per cent. carbon steel, while the corresponding percentage of those constituents is rather high in the 0·3 per cent. carbon quality. On the other hand, the difference in hardness between 0·6 and 0·7 per cent. of carbon is comparatively small, depending on the high percentage of manganese, in the former case, against a lower one combined with the higher percentage of carbon.

C.—*Hardening of Iron and Steel.*

It is now many years since Brinell began his investigation of the question how far and in what manner the properties of iron and steel might be influenced by different conditions of heating and hardening, and his results and conclusions have also, in some instances, been published. Thus, his well-known memoir on "Changes of Texture in Steel while Heating and Cooling" was published in 1885 in the *Jernkontorets Annaler*,* and is considered as a standard work. It has been translated into several languages and republished in a great number of foreign technical periodicals, and is also often referred to in metallurgical works of a more recent date. On the basis of the results thus made known, a "Graphic Table" has also been published, where the various conditions of hardening and annealing, especially with regard to the changes of texture, are diagrammatically shown in an ingenious and lucid manner. This table, which was brought to the notice of the members of the Iron and Steel Institute at the annual meeting held in Stockholm in 1898, and subsequently exhibited in Paris last year, was originally only intended as a guide for the use of technical schools and mechanics' institutes—as indicated by its modest heading—although it has no doubt also been found most useful in quite different and far wider circles.

* *Journal of the Iron and Steel Institute*, 1886, p. 365.

As might be supposed, the range of Brinell's researches included a means of applying his new testing method, and his next aim was to obtain a numerical expression for determining the various capacities for hardening met with in different kinds of steel, or in other words, to establish a means of ascertaining the "hardness capacity" of steel.

To begin with, it seemed to him that it would be sufficient for his purpose if the hardness number of the material were to be twice ascertained, the first time after previous careful annealing, the second after hardening, done in a certain, rational, and typical manner. The difference between the two hardness numbers thus obtained should then be the value required. In this way a number of researches were carried out, and the results have been published on the occasion of the Paris Exhibition. He has, however, subsequently found that such a mode of procedure does not quite answer the purpose, for the following reasons: The hardness number always depends not only on the percentage of carbon, but also to a considerable extent on the presence of other constituents. The sudden quenching of the material when heated hardly occasions any alteration worth mentioning with regard to those other matters, while, on the other hand, it causes the carbon to remain to a far greater extent in the state of hardening carbon than would be the case if the material was left to cool down slowly without disturbing the retrograde process of the carbon resuming its carbide character. An adequate expression for the hardness capacity of a steel material ought to be arrived at without need for taking into account any other constituents than the carbon; and the easiest means of accomplishing this would seem to be by taking the term of "hardness capacity" in a somewhat altered sense, or so as to be expressed by the *ratio* of increased hardness and not by the *difference*, in which case the value required would be obtained by dividing the hardness number obtained after hardening by the one obtained before, instead of subtracting the previous hardness from the one acquired by hardening, according to the scheme originally devised by Brinell.

The object of this alteration will be better understood by comparing two of the results obtained by Brinell, to be found in Table IX. In the case of the material No. 2 (C = 0·20

per cent., otherwise normal composition), the difference betwee the respective hardness numbers $(196 - 115)$ would be 8 while in the material No. 3 ($C = 0{\cdot}25$ per cent., otherwi normal), the corresponding difference would be $311 - 143 =$ 168. If those figures of difference were to be accepted as r presenting the hardening capacity of the respective material it is obvious that this capacity would be inferior in the materi No. 2, as compared with No. 3, by not less than 52 per cen $(\frac{168-81}{168} \times 100)$. But, on considering the somewhat unimporta difference in the percentage of carbon, only 0·05 per cent., su a result could not well be accepted as expressing any exa value, as two materials so slightly differing as to percenta of carbon, could hardly differ to such an extent in hardeni capacity. On the other hand, when by hardening capacity understood the ratio of hardness after hardening to th previous degree of hardness, which ratio indicates how man times harder the material has become in consequence of harde ing, the result would be, in the case of No. 2: $\frac{196}{115} = 1{\cdot}70$, an in the case of No. 3: $\frac{311}{143} = 2{\cdot}18$. This shows that the form material is inferior to the latter, as to hardness capacity, only b 22 per cent. $(\frac{2{\cdot}18 - 1{\cdot}70}{2{\cdot}18} \times 100)$, which is a rather more exact expre sion of the comparative value. Moreover, with this mode procedure the eventual influence of a superior percentage silicon is to a certain extent done away with.

Reference must now be made to a great number of exper ments made by Brinell while applying his new testing metho in order to ascertain various facts, conditions, and circumstanc connected with the process of hardening.

1. *Influence of the Percentage of Carbon on the Hardening Capacity.*

The results of those researches are contained in Table I and are also shown graphically in Fig. 6.

[redacted]

TABLE IX.—[illegible]

Material No.	Chemical Composition.					Hardness Numbers.		Hardening Capacity.
	C.	Si.	Mn.	S.	P.	Annealed.	Quenched in [illegible]	
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.			
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	0·25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	0·35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	0·45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6a	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	0·92	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	1·25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

From the above figures it appears that the hardening capacity increases with the percentage of carbon until 0·45 per cent., when it becomes nearly constant with the ascending rates of carbon up to 0·90 per cent., beyond which point there is a decrease. The lower limit is the one generally agreed upon as being the lowest one admitting of any hardening at all, or in other words, of the material acquiring, when heated and suddenly quenched, such a degree of hardness as not to be scratched by the file. A most interesting fact established by these results is that the hardening capacity thus proves to be fairly constant within so large a range of the steel region, there being no decrease to be observed except in the grades of steel with a somewhat high percentage of carbon.

2. *Hardening Effect of Different Quenching Liquids.*

The hardnesses of the steel used in these experiments, No. 1 ($C = 0·10$ per cent.), No. 5 ($C = 0·45$ per cent.), and No. 12 ($C = 1·25$ per cent.), were at first determined after previous annealing, and then after hardening by means of the respective quenching liquids mentioned below.

It must be remembered that the experiments of this class are by no means sufficiently analogous to those just described to

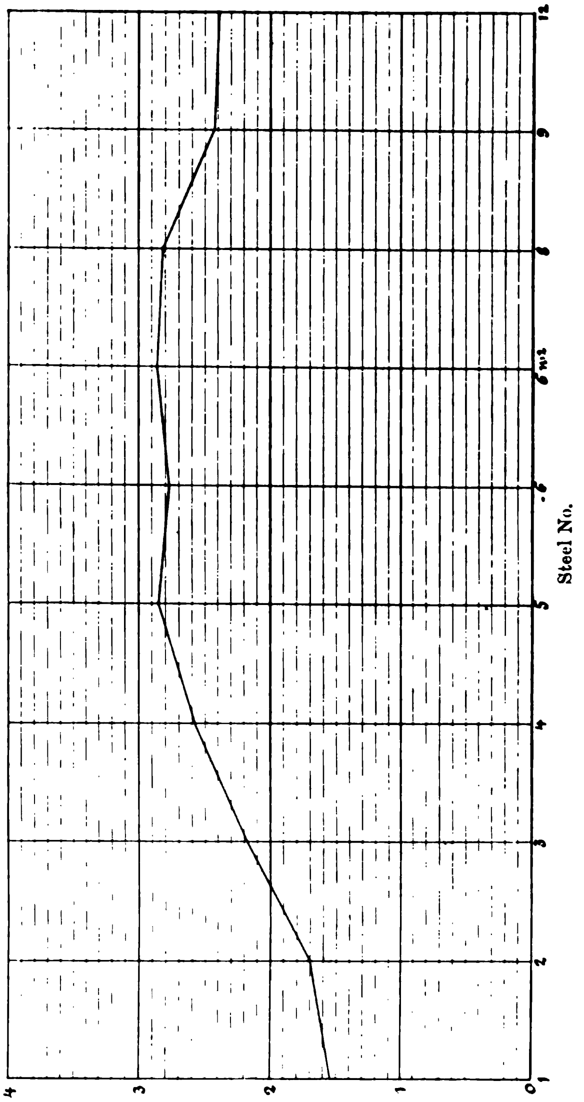


FIG. 6.

admit of a direct comparison of results of either series, these results being, in fact, only of a relative character within their respective classes. The two investigations were undertaken quite independently of one another, on different occasions, and there were, unfortunately, no arrangements made at the time to ensure the materials being similarly annealed in the corresponding experiments of each group, nor is there any certainty as to the hardening temperature having been more or less uniform. This is no doubt to be regretted, but at all events an opportunity is afforded of forming an accurate idea as to the relative value and importance of the results obtained with different materials within each group, as the treatment of the material was in each case identical in all experiments of the same series.

The results of these researches are given in the Tables X. to XIII., and are shown graphically in Fig. 7.

TABLE X.—*Hardening Effectiveness of Various Quenching Liquids. Temperature of Hardening*, 880° C.

Material.	Hardness Number. Before Hardening.	Hardness Number. After Hardening.	Hardening Capacity.	Quenching Liquid.
Steel No. 1. *Composition.* C =0·10 per cent. Si =0·007 ,, Mn=0·10 ,, S =0·020 ,, P =0·026 ,,	99	112	1·13	Lead, 350°
	,,	118	1·19	Boiling water
	,,	121	1·22	Skimmed milk, 20°-25°; horse suet, 80°
	,,	124	1·25	Wood tar, 80°
	,,	128	1·29	Churn milk, fresh milk, petroleum, 20°-25°
	,,	131	1·32	Tallow, 80°
	,,	134	1·35	Whey, sulphuric acid, 20°-25°
	,,	137	1·38	Soap solution, 20°-25° (1 soap, 10 water)
	,,	149	1·51	Common water, 20°-25°
	,,	156	1·58	Solution of salt (saturated), 20°-25°
	,,	202	2·04	Solution of soda (saturated), 20°-25°

TABLE XI.—*Hardening Effectiveness of Various Quenching Liquids. Temperature of Hardening*, 780° C.

Material.	Hardness Number. Before Hardening.	Hardness Number. After Hardening.	Hardening Capacity.	Quenching Liquid.
Steel No. 5.	202	217	1·07	Boiling water
Composition.	,,	223	1·10	Churn milk, 20°-25°
C = 0·45 per cent.	,,	235	1·16	Wood tar, 80°
Si = 0·27 ,,	,,	241	1·19	Lead about 360°!
Mn = 0·45 ,,	,,	248	1·23	Petroleum, 20°-25°
S = 0·018 ,,	,,	255	1·26	Horse suet, tallow, 80°
P = 0·028 ,,	,,	293	1·45	Skimmed milk, 20°-25°
	,,	302	1·50	Fresh milk, 20°-25°
	,,	402	1·99	Sulphuric acid (spec. gr. = 1·837), 20°-25°
	,,	555	2·75	Whey, 20°-25°
	,,	600	2·97	Soap solution (1 soap, 10 water), 20°-25°
	,,	627	3·10	Solution of salt (saturated)
	,,	652	3·23	Solution of soda (saturated), common water, 20°-25°

TABLE XII.—*Hardening Effectiveness of Various Quenching Liquids. Temperature of Hardening*, 780° C.

Material.	Hardness Number. Before Hardening.	Hardness Number. After Hardening.	Hardening Capacity.	Quenching Liquid.
Steel No. 12.	311	387	1·24	Boiling water; fresh milk, 20°-25°
Composition.	,,	430	1·38	Wood tar, 80°; skimmed milk, 20°-25°; lead, about 360°
C = 1·25 per cent.	,,	444	1·43	Petroleum, churn milk, 20°-25°
Si = 0·60 ,,	,,	460	1·48	Tallow, 80°; soap solution (1 soap, 10 water), 20°-25°
Mn = 0·20 ,,	,,	477	1·53	Horse suet, 80°
S = 0·010 ,,	,,	495	1·59	Common water, 20°-25°
P = 0·027 ,,	,,	312	1·61	Whey, solution of soda (saturated), 20°-25°
	,,	600	1·93	Sulphuric acid (spec. gravity 1·837), 20°-25°
		627	2·02	Solution of salt (saturated), 20°-25°

According to these experiments, it appears that there is a considerable diversity of hardening efficiency met with in different quenching liquids, and the results thus obtained ought to be of value, as a guide in particular cases.

A point of special interest to be noticed here is that the same quenching matter differs to a certain extent with regard to the hardening result, according to the material hardened. The order in which the various substances are to be ranged, according to the rates of hardening efficiency, not being the same in the case of steel No. 5 as in No. 12, &c., there is no possibility of ranging them into a constant series, independently of the material.

3. *Influence of the Temperature of the Quenching Liquid on the Hardening Result.*

It is generally known that a better hardening result will be obtained with cold than with warm water. It is, however, not so well known that there are certain quenching liquids which will prove to be more efficient when warmed. These experiments were made with steel No. 5 ($C = 0{\cdot}45$ per cent.), the test specimens being raised as far as possible to the same hardening temperature, by means of a special arrangement, viz., by the test bars being placed vertically in a turning stand within the furnace.

Table XIII. contains the comparative results of two series of experiments :—

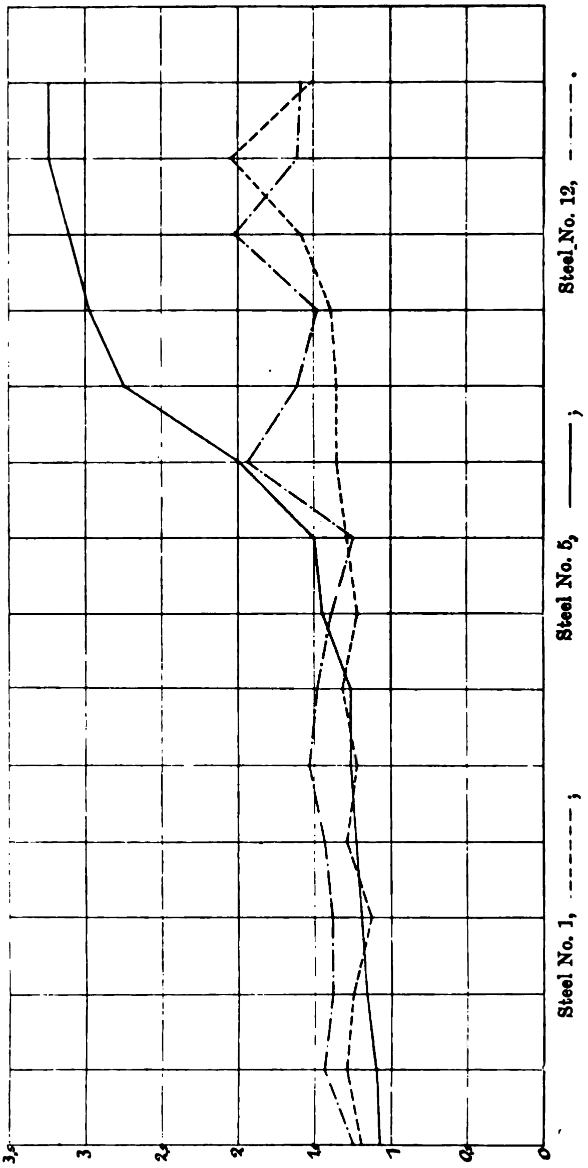
TABLE XIII.—*Influence on the Hardening Result of the Temperature of the Quenching Liquid.*

Material : Steel No. 5, uniform hardening temperature in both series.

	Hardness Numbers Obtained, Temperature of Quenching Liquid being	
	+ 15° to + 17° C.	+ 58° to + 60° C.
Whey	683	340
Common water	652	332
Freezing mixture (2 chloride of calcium, 1 snow)	652 *	683 †
Salt water	600	364
Solution of soda	444	627
Soap solution	418	283
Sulphuric acid (specific weight, 1·837)	311	430
Skimmed milk	293	285
Horse tallow	269	248
Tallow	255	293
Petroleum	248	241
Fresh milk	248	229
Churn milk	241	235
Wood tar	217	223

* Temperature of quenching liquid : − 20° C.

† Temperature of quenching liquid : + 15° C.



Hardening Capacity.

FIG. 7.

4. *Influence on Hardening Result of Different Hardening Temperatures.*

The object and purpose of hardening is not only to fix to the greatest possible extent, by means of sudden quenching, the carbon contained in the material in the state of hardening carbon, but also to obtain a steel the structure of which will be as finely crystalline as possible or amorphous. It is only when both of these conditions are complied with that a hardening operation may be considered successful. The proper hardening heat is fairly well defined within certain limits, both upwards and downwards, the lower limit being the temperature required in order to effect a transformation of the cement carbon into hardening carbon, below which there cannot be any hardening at all, except a certain hardness mechanically effected in consequence of the sudden cooling, and the upper one being the temperature which should not be exceeded in order to avoid the formation of a more or less coarsely crystalline structure, thus rendering the steel brittle, and at the same time hard. In Table XIV. are given some comparative results obtained by hardening at too high and too low temperatures, as well as at the proper hardening temperature.

TABLE XIV.—*Influence of Hardening Temperature on Hardness Result.*

Specimens after being heated up to the respective temperatures here indicated, quenched with water + 20° C.

Steel.				Hardening Temperature, 690° C.		Hardening Temperature, 750° C.		Hardening Temperature, 1000° C.	
No.	C.	Si.	Mn.	Diameter of Impression.	Hardness Number.	Diameter of Impression.	Hardness Number.	Diameter of Impression.	Hardness Number.
	Per Cent.	Per Cent.	Per Cent.	Mm.		Mm.		Mm.	
1	0·10	0·007	0·10	5·15	134	4·70	163	5·10	137
6	0·65	0·27	0·49	3·95	235	2·85	460	2·95	430
6a	0·66	0·33	0·18	4·05	223	3·10	387	3·10	387
7	0·70	0·32	0·22	3·90	241	2·25	744	2·25	744

D.—*Researches undertaken in order to ascertain the Homogeneous Properties of Iron and Steel, by means of Numerical expressions for Non-Homogeneity.*

The causes influencing the homogeneous properties of iron and steel may be classed in three principal groups, viz., segregation, implied by the solidification of the ingot, irregularities as to density or porosity, and finally, inequality of mechanical treatment.

The extent of the segregation depends on the speed at which solidification takes place. This again depends, in particular cases, on the size of the ingot, on the temperature of the liquid mass at the moment of casting, on the size and temperature of the moulds, and also on the chemical composition of the material. Segregation always requires a certain time, and consequently, the more rapid the solidification, the less thorough and extensive will be this process. This has been proved by practical experience; for instance, considerable defects of homogeneity, in the shape of conglomerate formations, are often to be found in the case of axles wrought from very large-sized ingots, or of laminated billets reduced from somewhat large dimensions, while, on the contrary, such defects are never, or at all events only exceptionally, met with in a material obtained from ingots of a moderate size, since such ingots are, in general, of a fairly uniform chemical composition. With regard to the casting temperature, the case is analogous; the higher the temperature the longer is the time required for the congelation, and the more complete the segregation.

As to the non-homogeneity caused by formation of blowholes, porosity, &c., it will suffice here to mention that such defects mostly occur in the upper part of an ingot.

A certain want of homogeneity in consequence of mechanical treatment is met with, more or less, in any wrought material, as the parts near the surface of course are more strongly affected by such treatment than the central ones, but only in exceptional cases is this of such importance as to cause any serious inconvenience. There are, besides, such irregularities as may possibly be due to an improper mode of mechanical treatment, either by certain parts having been less effectively worked than other ones, or by the treatment having been carried

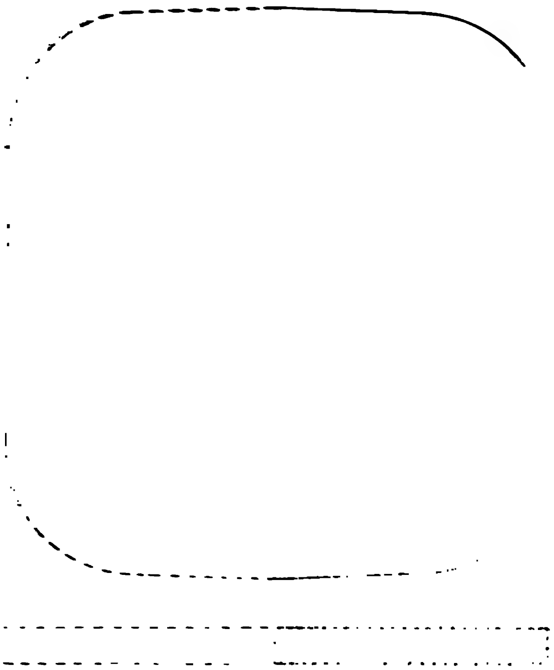


FIG. 8.

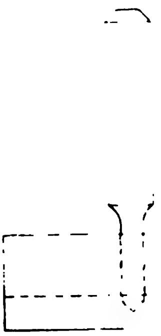


FIG. 9.

FIG. 9A.

too far in certain parts at too low a temperature. However, defects of this kind, although always to be considered as more or less prejudicial, are in general of a less frequent occurrence.

There is no doubt that the more or less homogeneous properties of a material are of considerable importance, and, according to Brinell, there ought to be some means of obtaining numerical values as expressions of non-homogeneity, while making use of his ball-testing method.

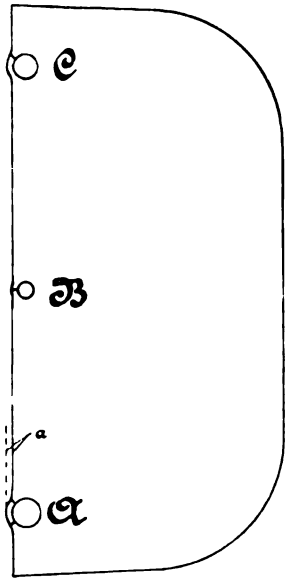


Fig. 10.

To this end he devised the following method: The test specimens required are obtained by cutting transverse sectional slabs from 4 to 10 millimetres thick from the steel billet to be tested. Each slab is vertically divided into two equal parts, as shown in Fig. 8 (specimen from a billet with round corners), one of the transverse surfaces, as well as the contiguous surface of the inside vertical edge, being finished by the file. At an equal distance apart, generally 2 millimetres from the smooth edge thus obtained, some rather slight indentations are then made in the finished transverse surface by means of a punch, for which purpose a special guiding contrivance, as shown in Fig. 9, should be used. The specimen thus prepared is placed in a compression test-machine, and a 5-millimetre ball is placed in the indentation, the burr of which should be removed with a file. The test pressure is then applied, preferably by manual power, but at all events in the slowest possible manner, the operation being at the same time closely watched by the operator, in order to enable him instantly to stop the test as soon as the least crack in the specimen is perceptible. This test is to be performed three times in the manner described in the case

of every specimen, namely, at the middle and each end of the central rim, or at the places marked B, A, and C (see Fig. 10).

In order to obtain the desired numerical expression of non-homogeneity, the various bulgings caused by the compression at the different points (A, B, and C) are then measured horizontally from the original rim, and denoting these respective measures by a, b, and c, the non-homogeneity number becomes

$$Nh = \frac{a+c}{2} - b$$

In Table XV. are found the respective results of three tests obtained by this method, while in each case the chemical composition of the material, and the corresponding tensile test results are also given. According to these results, a rather close analogy is noticeable between the values of non-homogeneity and the variations in chemical composition.

When examining the two charges, No. 3138 and No. 4288, as to the results of the tensile tests, no indication whatever is to be obtained as to non-homogeneity from the values of ultimate stress, while on the other hand, those of elongation do not admit of any doubt in this respect. On comparing the values ascertained by means of the tensile tests with those obtained by Brinell's method, it would appear that the latter gives rather more approximate and definite results. Thus, in No. 3138 the coefficient of non-homogeneity will be 3·7, according to the comparative values of elongation, ascertained by tensile tests, of the specimens from the core and the outside of the material, while the corresponding coefficient according to the ball test (measures of the different bulgings) is 4·7. With regard to No. 4288, the corresponding coefficients obtained by the tensile and ball tests are respectively 1·6 and 2·0.

It seems, however, that this method of procedure as proposed by Brinell for determining the homogeneous properties, or rather the non-homogeneity met with in iron and steel, can hardly yet be accepted as thoroughly satisfactory and fulfilling all requirements. The results thus obtained are probably only expressive

Table XV.

Charge No.	Specimen from Core or Outside Part of Ingot.	Chemical Compositions. C.	Si.	Mn.	S.	P.	Results Obtained by Means of Tensile Tests. Diameter of Specimen. Mm.	Yield Point. Kilograms per sq. mm.	Ultimate Stress. Kilograms per sq. mm.	Elongation on Fifty Millim.	Results Obtained by Means of Ball Tests. a.	b.	c.	$Nh = \frac{a+c}{2} - b.$
		Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.				Per Cent.				
3138	Outside	0·09	0·009	0·10	0·018	0·025	14	24·2	35·5	52	3·2	0·66	3·02	2·45
,,	Core	0·22	0·014	0·12	0·075	0·075	,,	20·3	35·3	14				
4288	Outside	0·32	0·26	0·43	0·018	0·027	,,	26·8	56·9	27	2·05	1·02	2·03	1·02
,,	Core	0·37	0·28	0·45	0·045	0·048	,,	28·1	58·2	17				
5532	Outside	0.78	0·30	0·24	0·010	0·022	,,	38·3	57·18	2	0·86	0·09	0·76	0·72
,,	Core	1·15	0·33	0·25	0·035	0·054	,,	48·4	68·87	2				

of non-homogeneity as to ductile properties, without the possible variations as to hardness and strength being taken into account. Probably this deficiency might be supplied by means of additional ball tests of hardness, there being always some means of combining the results obtained by such a twofold proceeding. According to the results obtained in a case to be

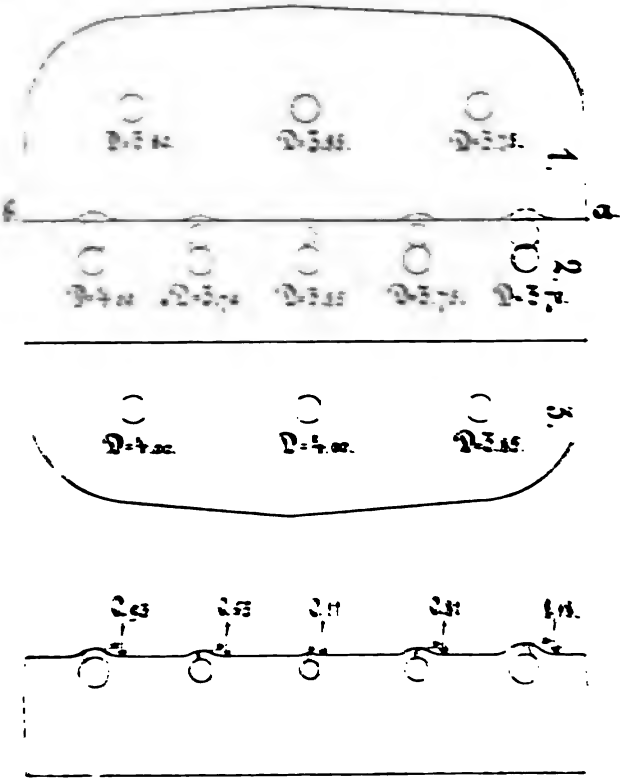


Fig. 11.

mentioned later, it appears, however, that the variations in hardness prove to be somewhat unimportant, as compared with the variations in the ductile properties shown by Brinell's non-homogeneity results. This assertion is also borne out by the fact that the results of the two tests for ultimate stress in the

case of both charges, No. 3138 and No. 4288 (Table XV.), about the same, while there is in both cases a quite conspicuous disparity between the elongation values. It would seem, then, that the superiority in hardness and absolute strength which the core of the material shows, on account of the segregation, as compared with the exterior parts, is not apparent, while on the other hand, the disparity as to ductile properties is quite strongly accentuated.

The case above referred to, as an instance of the hardness variations being of less importance, is found in Fig. 11, which does not require further explanation.

The maximum value of variation with regard to the ball test impressions is here given as—

$$\frac{4{\cdot}00-3{\cdot}70}{4{\cdot}00}\times 100=7{\cdot}5 \text{ per cent.},$$

while the corresponding value of the bulgings is—

$$\frac{1{\cdot}18-0{\cdot}11}{1{\cdot}18}\times 100=90{\cdot}7 \text{ per cent.}$$

The non-homogeneity number obtained in the case of this material, according to Brinell's method, is

$$\frac{1{\cdot}18+0{\cdot}93}{2}-0{\cdot}11=0{\cdot}95.$$

E.—*Annealing Temperature.*

With a view to obtaining some convenient and trustworthy means of ascertaining the degree of annealing in a particular steel material, Brinell has made several ball test experiments, the results of which are shown in the following Table (XVI.):—

Table XVI.—*Influence of Different Annealing Temperatures on Hardness of Steel.*

Material. Steel No.	Previous State directly from the Rolling Mill.		Annealed at Low Redheat, Cooled in Coal Dust.		Annealed up to White Heat, Cooled in Coal Dust.	
	Diameter of Impression.	Hardness Number.	Diameter of Impression.	Hardness Number.	Diameter of Impression.	Hardness Number.
	Mm.		Mm.		Mm.	
1	5·650	109	5·950	97	6·050	94
2	5·300	126	5·525	115	5·650	109
3	4·725	161	5·000	143	5·175	132
4	4·575	172	4·800	156	5·075	138
5	4·225	204	4·325	194	4·875	151
6a	4·000	228	4·250	202	4·750	159
6	3·800	255	3·950	235	4·500	179
8	3·675	273	3·975	231	4·525	176
9	3·575	289	3·775	258	4·375	189
12	3·500	302	3·750	262	4·150	212

F.—*Influence of Cold-Working.*

In order to ascertain how far cold-working affects the hardness of iron and steel, Brinell has made the following experiment:—

From two 25-millimetre steel bars, cold drawn and annealed, which contained respectively 1·2 and 0·25 per cent. carbon, were taken two specimens, distinguished as 1·2A and 0·25A. The remaining part of each bar was then drawn down to 24 millimetres, the section being consequently reduced by some 10 per cent., and the specimens of the material thus treated are denoted 1·2B and 0·25B. The comparative results obtained by means of ball testing in the case of each specimen are contained in the following Table (XVII.), according to which the increase as to hardness caused by this drawing operation is 25·5 per cent. in the case of the 0·25 carbon specimen, and only 11·9 per cent. in the case of the 1·2 carbon one. The conclusion to be drawn appears to be that by cold-drawing the hardness of a soft steel material will be increased to a far greater extent than in the case of a steel of superior hardness.

TABLE XVII.—*Influence of Cold-Working on Iron and Steel.*

Designation of Specimen.	Chemical Composition. C.	Si.	Mn.	S.	P.	Hardness Number.	Increase of Hardness Number in Consequence of Cold-Working.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.		Per Cent.
1·2A	1·20	0·33	0·18	0·012	0·027	88	11·9
1·2B	,,	,,	,,	,,	,,	89	
0·25A	0·25	0·06	0·40	0·020	0·028	45	25·5
0·25B	,,	,,	,,	,,	,,	56·5	

Another instance of hardness being increased by means of cold-working is also given by an experiment undertaken with a steel tube of 36 millimetres outside diameter. Several passes were given to this while in a cold state, without annealing or using a mandrel, until the outside diameter was reduced to 22 millimetres and the inside to 9·5 millimetres. This treatment caused the tube to crack afterwards all along one side, in consequence only of the excessive cold-working of the material.

According to the subsequent ball tests, the hardness numbers ascertained were, in the case of an unannealed specimen, 286, and in the case of an annealed specimen, 207.

G.—*Determinations as to Yield Point, Ultimate Stress, and Elongation in Iron and Steel.*

At a somewhat early stage of his researches, it occurred to Brinell that in the softer qualities at least of iron * and steel there should be some relation between the hardness number and the ultimate stress. Finding that this supposition was borne out by several preliminary experiments, he decided to undertake a more extensive series of comparative experiments, the material used being ordinary rolled Fagersta steel, without any other previous treatment. To this end two specimens of each kind of steel were taken, to one of which the tension test was applied, and to the other the ball test. The tension test specimens

* Here, as in general in this paper, the term iron means low carbon ingot steel, forge iron having never been used as a material in these experiments.

were forwarded to the testing-office of the Royal Technical High School at Stockholm, while the ball tests were carried out by Brinell himself at the Fagersta works. According to the test results thus obtained, Brinell found that when testing a material with a 10-millimetre ball, the maximum load being 3000 kilogrammes, the ultimate stress in kilogrammes per square millimetre was found by multiplying the hardness number obtained by means of the ball test by 0·346.

The results of these researches are contained in Table XVIII. given below, and are also graphically represented in Plate XVII. From these it appears that the ultimate stress, whether determined by the tension tests or obtained by means of ball testing, are quite sufficiently in accord for ordinary practical purposes, except when the percentage of carbon exceeds 0·8 per cent. Beyond this limit the divergence increases. As, however, the ultimate stress is of somewhat less importance in high carbon qualities, a quite remarkable prospect is nevertheless opened by these experiments. The advantages of being able to determine eventually by means of this ball-testing method, not only the hardness, but also the absolute strength of a material, are quite obvious, and do not need to be further enlarged upon at present. This would imply in a great many cases a considerable saving of time as well as of money.

It ought to be remembered, however, that the results of experiments made can only be regarded, for the moment, as a promising attempt, and by no means as implying any final results of a standard character. To begin with, no material has been used in these experiments but such qualities as are produced at the Fagersta works, and it is by no means to be taken for granted that the ratio determined by Brinell, by comparing the results of the comparative tests above mentioned, will prove to be constant in a general sense, independently of any difference as to chemical composition, or that what is true in the case of the Fagersta material will also hold good in the case of any other material. There is also another important question to be settled, namely, what may be the influence of different annealing on this ratio? These two questions will now be further examined into, according to the programme of investigations at present in progress at the

laboratory for testing material at the Royal Technical High School at Stockholm.

Brinell considered that while attempting to find a means of determining the ultimate stress, an attempt might as well be made at the same time to obtain determinations as to yield point and elongation.

TABLE XVIII.—*Comparative Results of Tension Tests and Ball Tests made in order to determine the Yield Point, Ultimate Stress, and Elongation in the Case of Identical Materials.*

Charge No.	Carbon per Cent.	Yield Point. Kilogrammes per Square Millimetre.		Ultimate Stress. Kilogrammes per Square Millimetre.		Elongation per Cent.	
		Tensile Test.	Ball Test.	Tensile Test.	Ball Test.	Tensile Test.	Ball Test.
3138	0·09	18·9	18·9	32·7	32·7	26·1	26·1
4958	0·18	22·6	13·4	40·0	42·0	24·8	24·7
4647	0·25	27·6	19·5	52·0	50·8	24·6	26·3
4288	0·34	28·0	32·4	55·1	54·3	23·6	22·6
4297	0·44	30·5	32·7	65·1	65·0	18·9	21·4
3096	0·64	34·4	35·7	77·1	77·5	13·4	15·7
1118	0·68	35·8	39·5	80·0	81·5	13·9	16·4
3958	0·49	44·4	34·7	85·7	84·0	14·8	17·4
3914	0·65	40·4	43·2	85·7	83·0	10·6	14·5
4642	0·79	40·4	42·5	89·6	88·5	10·0	10·8
4612	1·17	51·2	54·0	88·6	99·5	2·6	3·9
4729	1·13	50·1	41·8	90·8	102·0	2·6	3·8
4885	0·94	46·1	51·8	98·1	105·0	6·7	6·7
1829	1·05	50·1	46·2	101·0	105·0	5·7	6·0

As a means of ascertaining the yield point, he took as a starting-point the molecular alterations which suddenly occur in any material of iron and soft steel under the influence of a tensile or compression stress at the moment when the limit of yielding stress is attained. To these alterations is due the formation of what is called change of configuration (Fliessfiguren).

The method of procedure was as follows: A test specimen of the same size and shape as otherwise used in ordinary ball testing was prepared in a similar manner as in the case of the non-homogeneity tests described above. Besides finishing the testing surface, one of the contiguous edges was also prepared, and then a slightly concave impression was made in the former surface at a distance of 2 millimetres from the finished edge.

The same punching implement was used as described in the case of the former tests (Fig. 9). In the hollow thus obtained a 5-millimetre testing ball was placed. The subsequent compression test was then performed by gradually increasing the load most carefully and slowly, while closely observing the polished edge and contiguous surfaces. The specimen was so placed as to admit of a full and strong light being thrown on these parts. Exactly at the moment when the yield point was exceeded a dulness passed over the bright surface close to the spot where the ball was forced in, this phenomenon being due partly to the above-mentioned molecular alterations, and partly to a certain minute but quite perceptible bulging out of the material at that spot.* This was also the point at which the impression had to be discontinued, and the maximum load to be read off. This latter was, in general, found by Brinell to be proportional to the yield point, as determined by means of tensile tests. In Table XVIII. are also contained the yield point values obtained in the course of Brinell's comparative researches by means of comparative tests. When examining the results a little more closely, a conspicuous lack of agreement is apparent in the values obtained by means of the different tests as compared with the corresponding values of ultimate stress. This is, however, by no means surprising when the exceedingly difficult and delicate character of the ball test operation is considered. There are also, no doubt, other factors to be taken into account, which more or less influence the final result, but these are of a more occasional and secondary character, and have thus as yet escaped unnoticed. At all events, it is to be hoped that those difficulties will be overcome, and that some means may be found of rendering the comparative results as to yielding stress not less satisfactory than is already the case with regard to ultimate stress.

In order to obtain his value of elongation, Brinell used the same specimen and the same method as when determining the yield point, only he carried the operation further by increasing the pressure beyond the yield point limit until the first perceptible crack appeared in the material bulging outwards.

* While performing this test, there ought to be some precaution taken, for instance, by means of a glass screen, against the danger of bursting the ball, the 5-millimetre balls being less safe than the 10-millimetre ones.

The distance of the outermost point of the bulging, measured horizontally from the original rim, was then found to be proportionate to the value of the elongation as obtained by means of the tension tests. This whole proceeding was thus analogous to the one used in the non-homogeneity tests. The comparative values of elongation obtained by ball testing and by means of tension tests are also to be found, together with the corresponding values of ultimate stress and of yield point, in the above Table XVIII. The results of these researches are also graphically represented in Plate XVII.

If, as may be hoped, the experiments and researches described above should be confirmed by further experiments to be made with other materials of a more or less different chemical composition, this new testing method invented by Brinell will no doubt be turned to practical account on a most extensive scale. The tension test which now almost universally prevails is not only expensive and tedious, a twofold inconvenience of a somewhat serious character, but proves also, in a great many cases, quite impossible of execution, either because the quantity of material to be tested is insufficient for obtaining a test specimen of the size and shape required, or because there is no means of reducing the material to proper dimensions. If the ball test should prove to answer the purpose, as may be the case, within certain limits of hardness, this would considerably alter the aspect of the matter in question, since the test specimens might then be of almost any shape, and of a very small size (3 to 5 centimetres), without there being any need for elaborate preparation. A very few minutes only are necessary to prepare them. For instance, in the case of manufacturing ordnance, the compulsory tension tests always occasion heavy expense and a considerable loss of time. There is, to begin with, a good-sized piece required as a specimen, which must be bored out of the material, and then further prepared by turning it to the proper dimensions, after which it is finally to be stretched until ruptured. The entire operation requires, in general, a couple of days. On the other hand, for the ball test only a small specimen is necessary, which may be cut out from any edge or corner of the material, and the whole proceeding, including the needful preparation, can be completed within a couple of hours.

A general opinion is besides beginning to prevail as to the desirability of getting rid of the tension tests in such cases where purely practical tests only are needed, and this not only on account of those tests being somewhat costly, but more so perhaps on account of their having been found occasionally to be less trustworthy and even quite misleading. For instance, the values of elongation cannot always be accepted as a criterion of the ductile properties of a material when subjected to the action of an impact stress. Without entering into any further details of this important question, this fact at least should not be lost sight of.

H.—*Test of Blanks for Gun-Barrels.*

Whenever a delivery of blanks for gun-barrels is contracted for, no mention is made in the compulsory testing clause of any values except such as are to be obtained by means of ordinary tension tests longitudinally performed. But considering that the object and purpose of any such stipulations should be, in the first place, to ensure that the material to be tested possesses just such properties as will render it fit for its special use, the stipulation referred to hardly proves sufficient for this purpose. Such a tensile test might be quite sufficient in cases where the stress eventually to be endured will be slow and gradual, and where it acts in the longitudinal direction of the fibres of the material. But the material of a gun-barrel is not so strained when the gun is fired, the stress being, on the contrary, quite instantaneous, and at the same time acting not only in the transverse direction, but radially from within the material. When it is further considered that it cannot be taken for granted that, though mechanical treatment may increase the tensile strength of the material in the longitudinal direction, it will affect it to the same extent in the transverse direction, there seems to be one reason more for pronouncing the tension test unsatisfactory. Possibly the mechanical treatment, if carried on to a considerable extent at a rather low temperature, in order to realise the superior tensile properties required by the contract, might also prove to be productive of more harm than good.

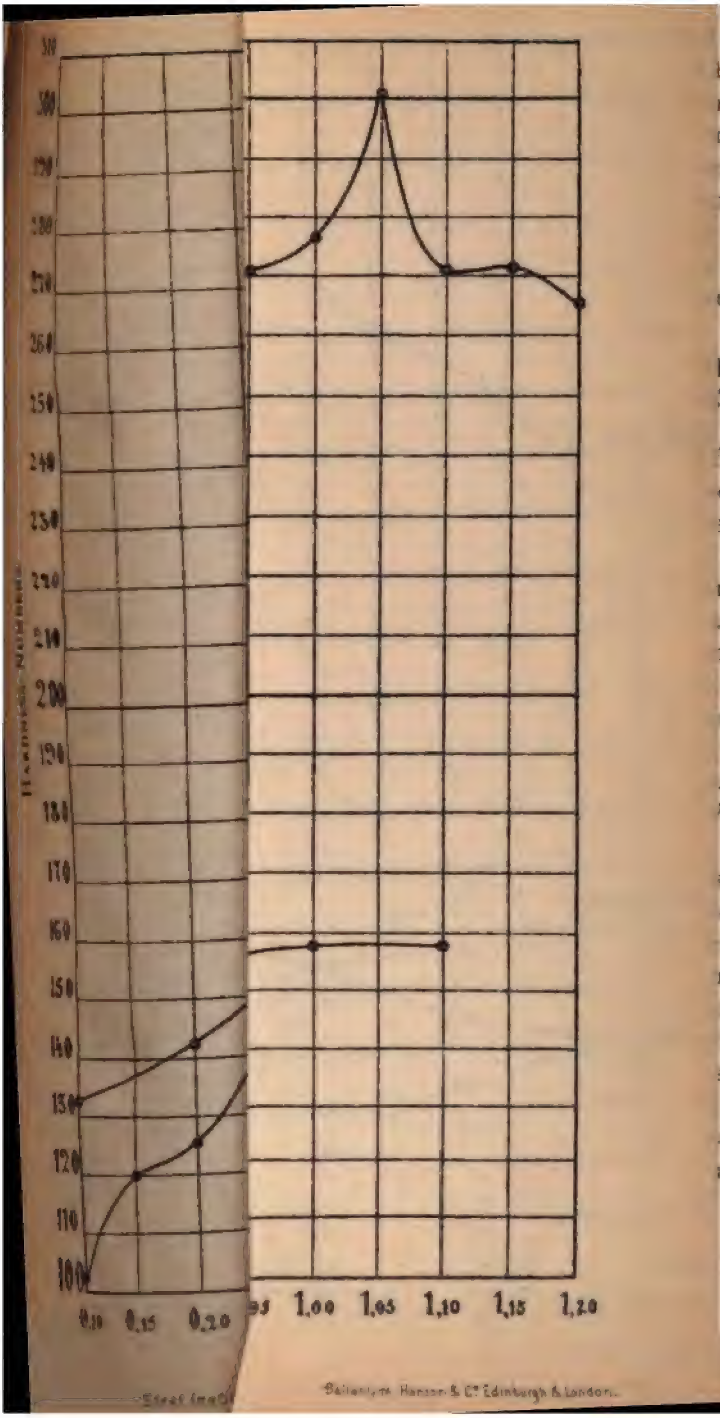
Regarding the matter from this point of view, Brinell was induced to make an attempt to devise some more prac-

tical means of testing gun-barrel material, a m
would give results expressing the effect of a
acting radially from out of the centre of the mat
fact, the case when firing a gun. Although not a
cation of the ball-testing method, it seems that
invented by Brinell for this purpose ought not to
here, the hardened steel ball being used as the test
in both cases.

TABLE XIX.—*Comparative Results obtained by Testing Gun-Barrels by means of ordinary Tension Tests,* *Brinell's New Method.*

Testing Method.	Determinations and Values as to—				Gun-barrel Steel, Fagersta Make, Round Section, Compressed according to the Fagersta Method.
Tension test in longitudinal direction.	Yield point, kilos. per sq. mm. Ultimate stress, „ „ Extension on 100 mm. per cent.				65·5 87·3 8·0
Impact tests by means of a hardened steel ball.	Strokes.	Dropping Height.	Dropping Weight.	Impact Effect.	Diameter of Enlargement of Tube. Millimetres.
	No.	Metre.	Kilos.	Kil. M.	
(Brinell's method)	1	0·1	5	0·5	0·
	2	0·2	„	1·0	0·
	3	0·3	„	1·5	0·03
	4	0·4	„	2·0	0·10
	5	0·5	„	2·5	0·18
	6	0·6	„	3·0	0·30
	7	0·7	„	3·5	0·43
	8	0·8	„	4·0	0·61
	9	0·9	„	4·5	0·79
	10	1·0	„	5·0	1·01
	11	1·1	„	5·5	1·24
	12	1·2	„	6·0	1·53
	13	1·3	„	6·5	1·72
	14	1·4	„	7·0	1·93
	15	1·5	„	7·5	2·14
	16	1·6	„	8·0	2·37
	17	1·7	„	8·5	2·73
	18	1·8	„	9·0	broke
	Total impact stress effect at the last stroke (incl.) before breaking				76·5 kilog. m.


0,75



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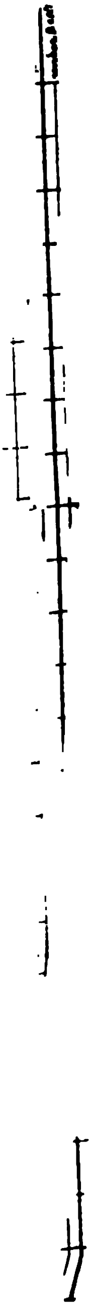


he proceeding is as follows: The specimen is bored and ed in the manner shown in Plate XVIII., an 11 mm. ball being lown into the tube, where it is stopped by the narrowing of bore downwards, while the strokes are applied on the top of lindrical rod of hardened steel, whose lower end rests on the . The dropping weight is 5 kilogrammes and the dropping ht of the first stroke 100 millimetres, increased by 100 limetres for every stroke, the impact effect being thus also eased in proportion. In Plate XVIII. is also shown the design he drop-hammer, as used in this test.

n Table XIX. are given the results obtained by comparaly testing two different materials, the one being Fagersta -barrel steel and the other steel of foreign origin, the ion of the Swedish blank being round, and that of the r hexagonal. There is also a certain difference caused by rent methods of manufacture, but specimens were taken of , in order that they might be tested both by tension tests also by Brinell's new method. According to the tension results, there is no difference worth mentioning as to lity in the two materials, although the foreign one is ewhat superior as regards toughness as well as strength.

When comparing the results of the impact tests the aspect natters is considerably altered. The Fagersta steel end not less than seventeen strokes before being ruptured, e the other material was ruptured at the eighth. When paring the impact effect in the respective cases, this rence is more strongly accentuated, the total impact stress sented by the seventeen blows in the case of the Swedish rial being 76·5 metre-kilogrammes, while the corresponding in the other case (seven strokes) is only 14·0 metrerammes. When considering the successive increase of the ping height, stroke by stroke, every subsequent stroke sents also a corresponding increase of impact stress, the last es being, in fact, essentially more effective than the first and it is found that the real difference as to quality met in the two materials is still more considerable than is ated by the above numerical values.

us by means of these comparative tests it is shown that ugh, according to the tension test, the foreign material was

found to be superior in a small degree as to toughness to the Fagersta steel, it proved to be quite the reverse when both materials were put to the test of a sudden stress acting radially from within. According to the drop test results, the enlargement of the material before being ruptured was more than six times greater in the case of the Fagersta steel.

The conclusion to be drawn from these results is, in short, that the foreign material was found to be, to a certain although rather small extent, superior to the Swedish one when being tested by means of a slow longitudinal stress, but that, on the other hand, the Fagersta steel proved to be most decidedly superior both as to strength and toughness when both were acted upon in a similar manner by a sudden and instantaneous stress, acting radially from within the material, or, in other words, when being acted upon in the same manner as is the case when a gun is fired.

There is no doubt that, in any case of tenders for the supply of gun-barrel blanks, there would be a better guarantee obtained by specifying testing conditions according to Brinell's method than by adhering to the old specifications which still prevail, requiring certain values of ultimate stress and elongation.

I.—*Influence of the Variations in the Percentage of Carbon, Si and Manganese on the Hardness of Iron and Steel.*

In accordance with the rule introduced in recent years at Fagersta Works, as already mentioned, the ordinary prac "forging tests" are always controlled in the case of e charge of open-hearth steel, by means of ball tests. At pouring of every charge, when about half of the molten has been run out of the ladle, a special test ingot, 75 metres square by 100 millimetres in height, is cast, the se of which is then reduced by forging to 28 by 28 millim A length of 65 millimetres is then cut off for use as a bal specimen. In order to ensure the uniformity of these mens, they are always subjected to a preliminary anne temperature of 800° C., and are then allowed to cool i open air.

On the occasion of the Paris Exhibition last year, B

showed a great number of ball test results, to obtain which no less than 1500 different charges were tested. This series of hardness tests is doubtless one of the most comprehensive ever carried out in the history of iron and steel.

Those test results are contained in a special general table given below (Table XX., see Plate XIX.), and are so arranged as to show at a glance in every case the respective influence of the carbon, silicon, and manganese. The same results are also graphically represented in Plates XX. and XXI.

On account of the very small and unimportant variations in the phosphorus and sulphur percentages of these compositions, no reference is made to these constituents. It is sufficient to state that the average percentage of the phosphorus was from 0·024 to 0·029 per cent. and of the sulphur from 0·005 to 0·02 per cent.

On referring to the general table, it will be noticed that these researches cover a wide range of carbon percentages, from 0·10 to 1·20 per cent. inclusive, while the variations in the manganese and silicon are shown to be respectively from 0·18 to 1·24 and from 0·10 to 0·74 per cent.

According to this table, the possible chemical combinations would number 1771, but the material available has of course been far from sufficient for producing such a number. In fact, there are only 286 different combinations represented in this series, and as the number of charges tested was 1500, each value given in the table may be taken to represent the average of about five charges. In reality, however, this is not quite the case, because several of the values were obtained as the result of testing about ten charges, while other values only represent a single charge. This is, of course, especially the case with regard to those charges of an exceptional chemical composition, such as, for instance, carbon = 0·40 per cent., manganese = 1·15 to 1·24 per cent., and containing at the same time 0·10 to 0·24 per cent. of silicon; or carbon = 0·30 per cent., manganese = 0·55 to 0·64 per cent., with 0·55 to 0·64 per cent. of silicon, &c. The comparative value of the hardness numbers, as indicated in the table, is therefore somewhat different in different cases, an inconvenience hardly to be avoided in such a comprehensive series. As a rule, however,

every value may be considered as an average value, obtained by means of testing several charges, several tests being also made in the case of each charge. In all cases, where more or less irregular or exceptional values were obtained, special care was always taken to verify, by means of repeated tests, whether such irregularities or exceptions could be accepted as real facts, or were to be attributed to accidental circumstances.

With such an abundance of material to go upon, the means are afforded of arriving at many valuable conclusions. It requires, however, the exercise of the utmost care to avoid being led astray, and the author, unwilling to incur this risk, permits himself therefore, on this occasion, to put forward only a few observations suggested by the preliminary study of the matter.

To begin with, it should be mentioned that the general table, as given in Plate XIX., differs somewhat from the one exhibited in Paris, in that the respective values for ultimate stress are for lack of space omitted. They are, however, to be easily found if desired, by multiplying the respective hardness numbers with 0·346. It must nevertheless be borne in mind, that this coefficient, which expresses the ratio between hardness and ultimate stress, is not to be taken as exact as soon as the carbon exceeds 0·8 per cent. Further, this ratio was only obtained by means of comparative tests, made exclusively with ordinary Fagersta steel, and is not yet authenticated by tests with other material of a different composition.

Chief among the questions arising from the comparative study of the influence of varying percentages of carbon, silicon, and manganese on the hardness of steel, is that which bears on the relative influence of those constituents when occurring together. As already stated, irregular and somewhat exceptional test values occur occasionally, and care must be exercised that the average results are not unduly influenced by these. Thus the average values should be obtained by making as many tests as possible. But the difficulty presents itself that in many cases, with regard to chemical composition, no values are available. By taking the average of the results contained in the general table (Plate XIX.), Table XXI., showing the relative influence alluded to, has been compiled, which indicates, in each case, the maximum and

minimum percentages of the other constituents occurring in combination with that one whose influence it is desired to ascertain, and also the number of tests. Since the influence of the silicon and manganese is essentially less than that of the carbon, it may be assumed that the average hardness values of this table, which increase in a ratio corresponding to the increase of the carbon percentage, are fairly exact. Particularly so when it is considered that the limits of variation of the other constituents are somewhat narrow.

In calculating the average values indicative of the influence of silicon, the percentages of carbon selected for this purpose are, as far as possible, those which are combined with the most widely varying silicon percentages, as contained in the general table. This is done for the purpose of obviating to the utmost such variations in hardness as may be due only to variations in the carbon. In certain cases, the values required to show the influence of the manganese, which are not to be found in the general table, have been obtained by means of interpolation. The values contained in this table are represented graphically in Plate XXII.

To gain a general idea of the influence of the respective values on the hardness result, the average increase of hardness was calculated for every 0·1 per cent. of the respective constituents until the point of maximum hardness was reached. As the table shows, the hardness number increased by 19·3 for every 0·1 per cent. of carbon, while the corresponding values with ascending rates of silicon and manganese were respectively 6·4 and 4·0. This again tends to prove the predominating influence of the carbon.

It is worthy of notice that the maximum point of the carbon curve is so strongly marked. While the maximum values of ultimate stress are generally obtained with about 1 per cent. of carbon, above which percentage there is generally a decrease of strength, it has always been considered that such is not the case with regard to compressive strength nor hardness. The latter property may reasonably be regarded only as a modification of the former one.

TABLE XXI.—*The Relative Influence of Carbon, Silicon, and Manganese on the Hardness of Iron and Steel.*

CARBON.			SILICON.			MANGANESE.		
Manganese, 0·2 to 0·6 p.c. Silicon, 0·1 to 0·5 p.c.			Manganese, 0·3 to 0·5 p.c. Carbon, 0·2 to 0·4 p.c.			Silicon, 0·1 to 0·2 p.c. Carbon, 0·2 to 0·4 p.c.		
Carbon, p.c.	Number of Values.	Hardness Number.	Silicon, p.c.	Number of Values.	Hardness Number.	Manganese, p.c.	Number of Values.	Hardness Number.
0·10	2	103	0·10	12	133	...	...	...
0·15	3	120	...	...	...	...	...	...
0·20	10	126	0·20	12	143	...	...	...
0·25	13	141	...	...	...	...	...	...
0·30	14	149	0·30	7	156	0·30	4	130
0·35	15	163	...	...	...	...	...	...
0·40	13	166	0·40	10	157	0·40	4	134
0·45	7	181	...	...	...	...	...	...
0·50	8	205	0·50	6	159	0·50	4	140
0·55	8	221	...	...	...	...	...	...
0·60	15	229	0·60	9	165	0·60	4	141
0·65	15	230	...	...	...	...	...	...
0·70	14	238	0·70	5	163	0·70	4	143
0·75	11	248	...	...	...	...	...	...
0·80	10	256	...	...	...	0·80	4	147
0·85	7	260	...	...	...	...	...	...
0·90	10	270	...	...	...	0·90	4	154
0·95	8	271	...	...	...	...	...	...
1·00	11	277	...	...	...	1·00	4	158
1·05	6	301	...	...	...	...	...	...
1·10	5	271	...	...	...	1·10	4	158
1·15	4	272	...	...	...	...	...	...
1·20	6	266	...	...	...	...	...	...
Average increase* of hardness number, for every 0·1 p.c. C=19·3.			Average increase* of hardness number, for every 0·1 p.c. S=6·4.			Average increase* of hardness number, for every 0·1 p.c. Mn=4·0.		

* Until the maximum value be reached.

There do not seem to be any more comprehensive researches than these available on this subject. According to the compression tests made by Kirkaldy, in connection with his extensive researches on Fagersta steel at the time of the Vienna Exhibition, which included a series of tests with rates of carbon ascending from 0·3 to 1·2 per cent., the compression strength was shown to increase continuously. But these experiments were not sufficiently numerous to admit of drawing any trustworthy deductions. This is also pointed out by Howe.* This

* "The Metallurgy of Steel," p. 17.

writer seems inclined to assume that the increase in hardness in proportion to ascending rates of carbon would prove to be unlimited, although, for lack of sufficiently authenticated facts in support of such a theory, he does not express a definite opinion on the matter. In most other metallurgical works there is practically no mention whatever made of this property in steel. In view of these circumstances, it becomes the more important to verify Brinell's results by proving their real value, and a few more remarks by the author on certain details may therefore be permitted. On comparing the values obtained for the higher percentages of carbon in the general table (Table XX., Plate XIX.), the following results will be noted:—

(1) Mn 0·18—0·24 per cent., the maximum value occurs in one case with C = 0·9 per cent., in another with C = 1·05 per cent., and in a third case with C = 1·10 per cent.

(2) Mn 0·25 — 0·34 per cent., the maximum value occurs in one case with C = 0·95 per cent., in another with C = 1·05 per cent.

(3) Mn 0·35 – 0·44 per cent., the maximum value occurs with C = 1·00 per cent., but is not well defined.

It would, no doubt, have been more satisfactory had the series been more complete within the range of the higher percentages of carbon, but it seems probable that *the maximum hardness is obtained, in the case of annealed steel, at a carbon percentage of about* 1·05 *to* 1·10 *per cent.*

The influence of carbon on the hardness of iron is essentially different at different percentages of carbon. In this respect Howe * quotes some of Kirkaldy's experiments as showing that the influence of carbon on the compressive strength of iron and steel is strongest between 0·3 to 0·6 per cent.

Brinell's researches reveal the existence of a similar law with regard to hardness, since it appears, according to Table XXI., that the increase of the hardness number for every 0·1 per cent. of carbon is: with the ascending rates of carbon ranging from 0·1 to 0·3 per cent. = 23; from 0·3 to 0·6 per cent. = 27; from 0·6 to 0·9 per cent. = 14; while from 0·9 to 1·2 per cent. there will be a decrease = 1.

According to the same table, XXI., it also appears that the hardness effect of silicon, as determined by Brinell, is exactly one-third of the corresponding effect of carbon $\left(\frac{6\cdot4}{19\cdot3}\right)$. This ratio

* "The Metallurgy of Steel," p. 17.

is constant in the case of all carbon percentages from 0·2 to 0·4 per cent., together with 0·3 to 0·5 per cent. of manganese. These limits are, no doubt, somewhat narrow, but the number of tests, by means of which the respective average ratios have been attained, is very considerable. At the same time, most of the test values to be found in the general table represent several charges, and thus acquire a certain importance. It will be seen further from the same table, XXI., and also from the graphic representation on Plate XXII., that there is a certain maximum limit to the influence of the silicon not less than to that of carbon, although much lower in the former case. This limit is reached at 0·6 per cent. of silicon, while in the case of carbon it occurs at about 1·05 per cent. According to this table and the corresponding graphic representation, it is found that the increase of the hardness effect produced by the silicon is very much greater within the range of lower percentages than at higher ones. Thus the increase of the hardness number with ascending rates from 0·1 to 0·3 per cent. is equal to 23, while from 0·3 to 0·5 per cent. it is only 3.

This result is quite consistent with the more recent experience of the real influence of silicon as a constituent of iron and steel. It would seem, in fact, as if the old prejudice against this metalloid is losing ground, and steel is now frequently made which contains a comparatively high percentage of silicon. More particularly in the case of certain kinds of tool-steel, it is found that steel which contains a fairly high percentage of silicon works without crumbling, nor does it, on account of the silicon, lose its capacity for hardening.*

As to the hardness effect of manganese on iron and steel, according to Table XXI., it is not far from one-fifth of the corresponding effect of carbon $\left(\frac{4}{19 \cdot 3}\right)$. As in the case of carbon and silicon, the increase of this effect with ascending rates of percentage is more considerable within the range of lower percentages, while a corresponding decrease is apparent beyond a certain percentage of manganese. The maximum hardness occurs at 1 per cent. of manganese, and even at 1·1 per cent. It is to be regretted that the series of results contained in the

* *Jernkontorets Annaler*, 1900, p. 86.

general table is rather incomplete as to the higher percentages of manganese, and does not admit of ascertaining whether any decrease in hardness takes place at these percentages.

On comparing the results contained in the general table with the graphical representations in Plates XX. and XXI., it is seen that numerous and somewhat sharply accentuated irregularities occur. Thus, for instance, in the columns of the general table giving the combinations of 1 per cent. carbon with 0·45 to 0·54 per cent. manganese and 0·10 to 0·74 per cent. silicon, the respective hardness numbers are—

With 0·2 per cent. of silicon	306
,, 0·3 ,, ,,	284
,, 0·4 ,, ,,	259
,, 0·5 ,, ,,	311

Another instance is seen in the case of 0·50 per cent. carbon combined with the same percentages of manganese and silicon as above when the hardness numbers are—

With 0·2 per cent. of silicon	203
,, 0·3 ,, ,,	187
,, 0·4 ,, ,,	219
,, 0·5 ,, ,,	235

Similar irregularities are also to be noted in several combinations containing 0·45 to 0·54 per cent. manganese where the carbon exceeds 0·5 per cent. The lowest hardness number, then, as a rule, corresponds with 0·3 to 0·4 per cent. of silicon. Thus it seems as if "critical compositions" occasionally occur in a not less degree than critical temperatures. The latter are indicative of certain variations in the magnetic properties of iron, and also of a certain transformation of the carbon, which is accompanied by certain alterations in the mechanical properties.

The following may be cited as instances of critical combinations occurring within the series of ascending rates of carbon:—

In comparing the test results in combinations with 0·25 to 0·34 per cent. manganese and 0·35 to 0·44 per cent. silicon, it is to be seen that—

With a percentage of carbon of 0·75 per cent. the hardness number is	251
,, ,, ,, 0·80 ,, ,, ,,	255
,, ,, ,, 0·85 ,, ,, ,,	261
,, ,, ,, 0·95 ,, ,, ,,	291
,, ,, ,, 1·00 ,, ,, ,,	233
,, ,, ,, 1·05 ,, ,, ,,	269
,, ,, ,, 1·10 ,, ,, ,,	269
,, ,, ,, 1·20 ,, ,, ,,	290

A marked irregularity is noticeable at 1·00 per cent. of carbon. In the series of experiments with ascending rates of manganese it is more difficult to obtain a true comparison of results, owing to a want of continuity in the series.

The following instance occurs in the case of the combinations 0·90 per cent. carbon with 0·10 to 0·24 per cent. silicon, which give—

With 0·2 per cent. manganese the hardness number . .	265
" 0·5 " " " " . .	255
" 0·7 " " " " . .	255
" 0·9 " " " " . .	266
" 1·0 " " " " . .	293
" 1·1 " " " " . .	321

The critical composition here appears to be that of 0·5 to 0·7 per cent. manganese.

These two instances are perhaps a sufficient proof of the occasional occurrence of what are here called "critical compositions." Any attempt at further investigation with the object of classifying the respective cases is rendered impossible owing to the insufficiency of the number of test results, although the number of open-hearth charges tested was not less than 1500.

In compiling Table XXI. it was found possible, by keeping within very narrow limits, to obtain certain average values which it is to be hoped will be found fairly trustworthy, but all attempts to lay down a fixed rule for determining and regulating the "critical compositions" have hitherto proved futile.

It should be mentioned that the percentages of silicon given above, including even the lower ones, are considerably higher than those generally met with in Swedish iron.

In conclusion, the author desires to express his great regret that Mr. Brinell has been unable to find time to prepare a paper describing his own labours and their results. In the circumstances he has ventured to undertake the task, under the conviction that the subject is one of great importance, and well worthy of the attention of the Iron and Steel Institute. The concluding portion of the paper will be submitted at the autumn meeting.

DESCRIPTION OF THE BESSEMER SHOP AND HEATING PITS AT THE BARROW HÆMATITE STEEL COMPANY'S WORKS, BARROW-IN-FURNESS.

By J. M. WHILE, M. Inst. C.E. (Barrow-in-Furness).

esponse to a request from the Council of this Institute that ould read a paper on our newest plant at Barrow, I have sure in placing before the members a description, accomed by drawings, of our comparatively new Bessemer shop and ing pits; but before proceeding to do so I will briefly relate changes which had become necessary in this department of Company's works in order to keep up with the advance made ience and practice.

n the year 1865 the Company, after having experimented small way, erected converters of 5 tons capacity, which followed by others of 8 tons capacity, and there were ing for a period as many as eighteen converters; as the men me more used to their work, and appliances became better ted, the production of each converter was augmented suffitly to permit of a reduced number being used, but there still ined so late as 1896 eight converters of 8 tons capacity, ucing a total quantity of about 6000 tons of ingots weekly.

n the year 1896 a new shop was built, which commenced ations early in 1897; this consisted of four converters of tons capacity each, and these will chiefly form the sub- of the paper. How long it may be before these also will e to be replaced, it is impossible to say; but when it does e about, it is more likely to be through a change in the ess of steel-making than a still further enlargement; and le it may be regrettable that such continued expenditure ld be necessary, the fact that such changes are made at least vs that when economies are known to result from it, English- are not so backward in enterprise as some writers would e us believe.

n giving to the Institute the description and details of this semer shop, I have no wish to claim originality for any part

of it. The shop and machinery were designed, constructed, and carried out entirely by the officials and workmen of the Company, and all the plant, including the converters, cranes, ladles, and ingot stripper, have been made at the Company's own works; and while it may be that no one contemplates the erection of a Bessemer plant, it is hoped it may be found that some of the details may be of service in the design of other steelworks plant, and if this be so, the Journal of the Institute appears a convenient place for them to be recorded.

The Bessemer shop comprises four converters, each of 20 tons capacity, arranged in one row, and facing what is generally known as the pit. They are made of 1-inch steel plates, and encased by wide cast steel rings, on which are made to grip the trunnions, which are also fastened to them by rivets. The converters are elevated sufficiently to permit of a ladle standing on a crane below receiving the contents of steel, and also that a bogie on a road beneath the converter can receive the slag. Each converter is actuated by means of a powerful pair of vertical hydraulic rams, with racks and pinion acting in opposite directions.

In front of the converters is a platform supported by iron columns, to which access is obtained by an inclined roadway, along which the molten iron is brought from the mixer in ladles of 18 tons capacity. These ladles are made of steel five-eighth inches in thickness, encased as the converters are by rings, but with this difference, that the trunnions are cast in one with the rings. It will be noticed that the trunnions are not central, but are in such a position as will, during tipping, throw forward the contents of the ladle into the mouth of the converter. There is also cast on this ring a lug for supporting the ladle. The locomotive places the ladle of iron in front of the converter mouth, a hook engages itself on to a pin fastened on the ladle and lifts it up gradually until the whole of its contents are poured into the converter. When the ladle is emptied it is again lowered on to the carriage and returned to the mixer to be re-filled.

Spiegeleisen is charged into the converter in the same manner, the cupola being at one end of the platform, and on the same level as the converter. One cupola of the ordinary type,

having a blast pressure of two pounds, is found to be amply sufficient for the melting of the necessary spiegeleisen. The appliance used for lifting the ladle is that of a pair of rams, supported by lattice girders 21 feet above the staging, to which are attached chains serving the four converters. Scrap is charged chiefly before pouring in the molten metal, though, when necessary, additions are afterwards made from a platform fixed near to the mouth of the converter. At the back of the converters there is also an inclined roadway parallel to the one in front, which is used for the waggons supplying the scrap and tuyeres. The equipment of the shop includes underneath each converter a lift, which is used for the purpose of lifting and fixing into position the plug or bottom. Over this lift is a roadway, on which at all times stand a truck, which receives the slag as it leaves the converter. The converters are attended below by two transfer cranes, on which are placed the ladles for receiving the steel; these cranes transfer the ladles to a centre or casting crane, from which the heat is cast into moulds. In addition to the ladle cranes there are two smaller ones, which serve for changing the ladle or any other work. All these cranes, whilst of different sizes, are of the same principle, the top supported pillar having a wheel actuated by a ram and rack for the turning movement. This is very simple, and is found to work admirably. The cranes are worked from the ordinary distributing box, from which the converters and lifts are also worked.

It will be seen that underneath the jib of the casting crane there is a support, which prevents any accident through a possible breakage of the pressure pipe or a failure of the water-supply through any cause whatever; for once the ladle is placed in position, the heat can be cast independently of hydraulic pressure.

All the moulds are placed on bogies, each bogie carrying two. They move forward under the nozzle of ladle as required, the centre crane remaining stationary. As the position of each mould has to be very exact, so as to prevent a cutting action by the stream of fluid, as well as loss by bad pouring while casting, the bogies are moved along by means of a finger fixed on a ram, which is situated on the floor level. Dispensing with the movement of the large crane in casting is not only a safer method, but ensures a great saving in water pressure.

All the moulds are of one size, being made to hold 2 tons of steel, and in order that the arrangement of casting should work well, about 100 bogies are always in use; the consequence is, that there is a constant stream of bogies and moulds in circulation, and by keeping them running in proper order the moulds become cool by the time they are required, without recourse to water cooling; the advantage of this is well known.

At the back of the Bessemer shop there is a shed set apart for the special purpose of making plugs. These are made from tuyeres 26 inches in length, and the materials used for ramming are pure gannister and tar, the latter having been warmed and drawn from the bottom of the tar tank to ensure freedom from water. When the plugs have been stoved for about eighteen hours they are put into stock, and always allowed to remain there at least two weeks; if used earlier, they are not found to answer nearly so well.

Returning to the shop. When the ingots have remained in the moulds about ten minutes the bogies are drawn forward to the ingot stripper. This is a very useful machine, which, with a minimum of labour, strips the moulds from the ingots, and places them on to an empty bogie that they may return and so take their turn for a re-cast.

The ingots still on the bogie, but stripped of their moulds, are taken to two gas-heated pits by a locomotive. These gas-heated pits take the form of a long passage or channel 4 feet 6 inches wide and 7 feet deep, at either end of which is a set of regenerators. There are five lids to each pit, and they hold twenty ingots, that is to say, four ingots under each lid or door.

The doors or lids are of cast iron lined with bricks, and are supported by girders, on which the four wheels of each lid run during the opening and closing. These doors are moved by a rack and pinion actuated by a small hydraulic ram, there being a clutch for each door. Each pit is served by a small crane, similar to the serving cranes in the Bessemer shop, but with the addition of a racking-in motion; this movement is obtained by admitting water down the centre of each pillar to a ram placed on the jib, the connections being made possible by the use of walking joints on the top. All the movements of this crane are done by a lad perched in a high position, enabling him to see all the ingots in

the pit, and at the same time to have all his attention on his work. The dogs in use for charging and drawing these pits are very good. They were first seen by the writer while on a visit to the Homestead Works, and on his return were immediately adopted, and have been in use ever since. They are so made as to enable the man in charge to fix open the jaws until the exact moment for gripping, when, by a slight turning movement of his hand, the ingot is gripped.

When the ingots have remained in these pits a sufficiently long time they are taken out and placed on live rollers, and conveyed to the cogging or blooming mill.

Having briefly described the shop, I would say that the chief advantages it has over the old system are—

(*a*) The use of molten metal in larger quantities, saving haulage and ladle skulls.

(*b*) Pouring metal direct into the mouth of the converter, dispensing with the use of runners.

(*c*) Blowing larger quantities of metal, reducing the cost of bricks, tuyeres, steam and hydraulic power.

(*d*) The transfer of all material to one centre crane for casting, saving labour and hydraulic power, as well as providing the hot ingots for the mill in one constant stream, in place of the old intermittent way, when four different casting pits and ladles were in use.

(*e*) The casting of ingots in moulds resting on bogies in place of using pits, saving pit labour and hydraulic power, as well as being considerably safer.

(*f*) The ingot stripper saving moulds and much labour.

(*g*) The ingots are conveyed to the mills by locomotive power, saving labour.

(*h*) The use of heated pits, saving loss by oxidation, fuel, labour, and expediting the work.

The Bessemer shop was erected at considerable inconvenience, as it had to be accomplished while yet keeping the old one running, and on a part of its site.

The net cost to the Company was £23,000, and the saving effected by its use is about 2s. 5d. per ton of ingots produced, made up as follows:—

Increased yield of good ingots, 2 per cent.	
Saving in fuel, 45 lbs.	
Saving in moulds	
Saving in wages	
Saving in tuyeres, bricks, gannister, &c.	
Less extra locomotive power	

The heated pits, and live rollers which conve the rolls, were put in at a cost of £4500, and sav heating furnaces about 1s. 7d. per ton of finishe in the following manner:—

Fuel	
Labour in heating, bogeying, and charging	
Waste	

The combined saving being about 4s. per ton, o £40,000 per annum.

As is well known to most members of this Ins many difficulties to overcome when radically chan of working, but in addition to those ordinarily met one unforeseen, which was so important as to be

When it was first decided upon to put in th Bessemer plant, the idea occurred that we s American practice, and blow our heats in less customary in this country, with the further obj already specified of saving fuel, wear and tear of ou life of the converter lining and bottoms; and in with the same pressure of blast as we had hitherto u maximum, we so increased the diameter of the co as would enable us to use a larger number have a shallower bath. The converter was the to hold conveniently 20 tons of metal, and the b thirty-three tuyeres, each tuyere having nineteen sixteenths of an inch diameter, or about the power per ton as the smaller vessels had.

It was hoped that this shallower bath would

PLATE XXIII.

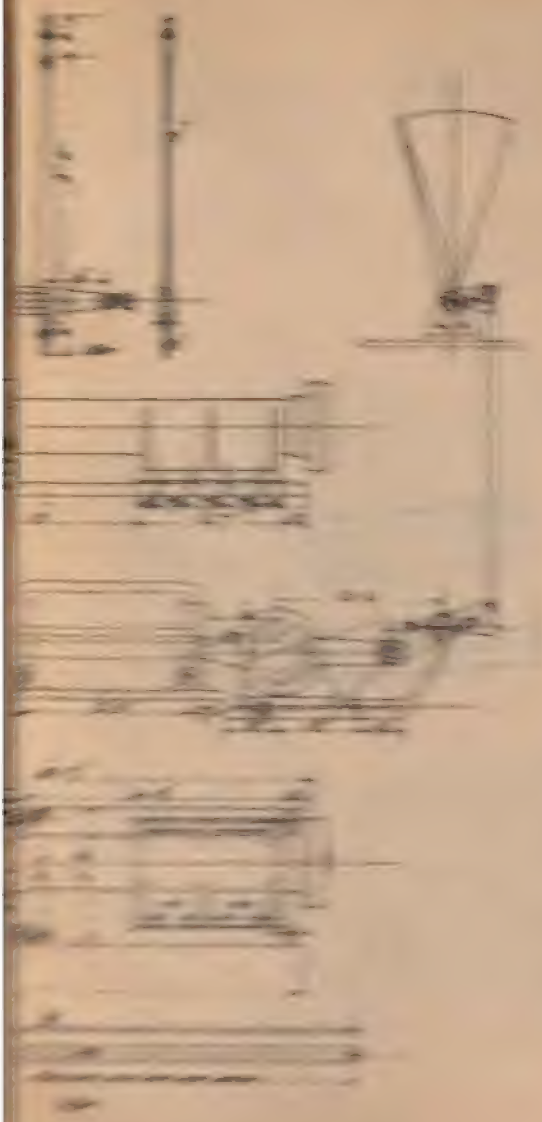
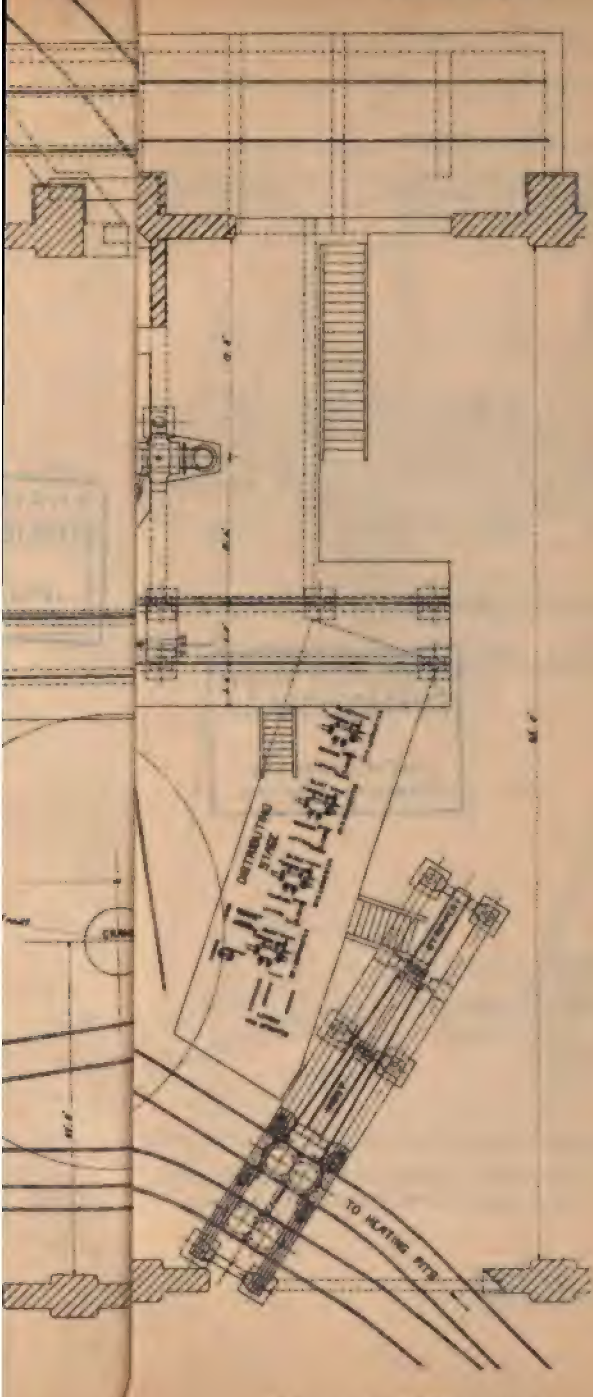


PLATE XXIV.

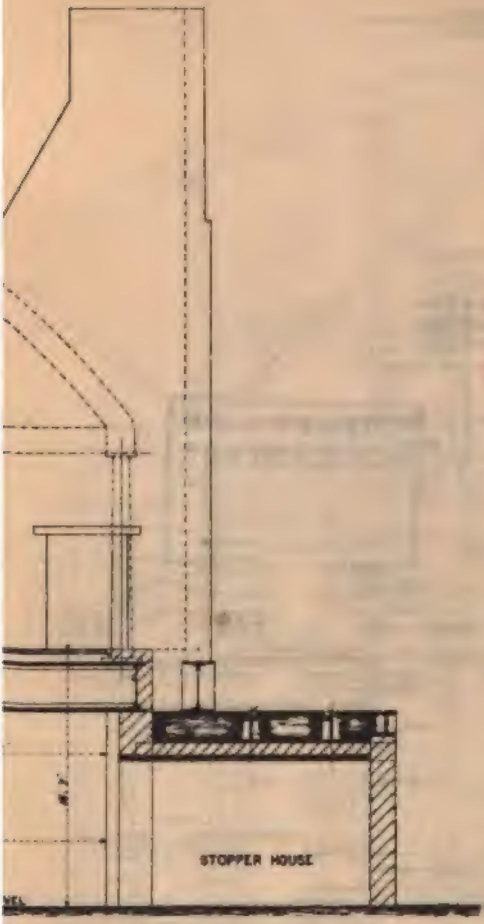


Ballantyne, Hanson & C° Edinburgh & London.

PLATE XXV.

Ballantyne, Hanson & Co Edinburgh & London.

PLATE XXVI.



Ballantyne, Hanson & Co. Edinburgh & London.

PLATE XXVII.

—hat the converter bottoms and lining would run for a —riod, probably twenty to thirty blows. The result was to our expectations; for while we were able probably for time in this country to blow our heats in ten minutes, —ome cases eight minutes, the blow was so hot as to be —ly unmanageable even when cooled by steam and large —es of steel scrap. The amount of material thrown out —essel equalled from twenty to twenty-five per cent. of —ge. The steel was so hot as to destroy the bottoms and in one cast, and the resulting steel worked badly. The —er bottoms being then made of gannister lasted only one heats, and the lining of the converter fared badly. It —ourse seen at once that fast blowing for the iron we had at —d was not practicable; we therefore reduced the number —res to twenty-seven, and increased the depth of bath. —used the time of blowing to extend to fifteen minutes, but —ot until we further reduced the tuyeres to twenty-four and —d the time of blowing to from twenty to twenty-five —, and still further increasing the depth of the bath, that —ined the present advantage from our Bessemer shop, and —teel of the best and most uniform quality.

object in giving the above information is, that it may be —nown that the faster working in vogue in the United States be introduced into England with advantage, for the same —ons do not apply in each country.

—h regard to the capacity of production, the shop has never —ut to its test, as the make is limited to the quantity of iron available; we have, however, without difficulty made tons weekly, and see no reason why fifty per cent. more not be produced if necessary.

—wings illustrating the car pusher, the general arrangement Bessemer plant, the arrangement of the ingot stripper, the —al elevation of the Bessemer plant, the gas heating pit, and —ngs used at the heating pits are appended (Plates XXIII. —VII.).

MEASUREMENT OF YOUNG'S MODULUS FOR IRON RODS BY TENSION AND BY BENDING.

BY H. E. WIMPERIS, B.A. (CAMB.), WH.SC.

ONE of the effects of passing iron through rolling-mills is to draw out any slag or other impurities that may be contained in the iron into long striations or thin layers. This result should show itself by giving the metal, considered as a bar, a different value for Young's modulus across the fibres from that measured along them, since in bending the layers of metal would slip relatively to one another, and the action would roughly approximate to that of a bundle of rods. It was suggested to the author by Professor Ewing that it would be of interest to investigate the matter by measuring E for a long rod by tension in an ordinary testing machine and comparing this value with that found by experiments on pure bending. If it were found that the value for E determined in the second case was less than that obtained in the first case, then it might be concluded that some such effect as that mentioned above had taken place.

Three specimens were used, and it will be convenient to refer to them as A, B, and C. A was a specimen of Swedish iron that had been cold-rolled after annealing. B was a specimen of Swedish iron that had been close-annealed after cold-rolling. C was a specimen of Lowmoor iron. A and B were obtained from Messrs. Edgar Allen & Co., Ltd., of Sheffield. B was included in order to determine the effect of annealing. All specimens were as nearly as possible of half-an-inch diameter.

The tension experiments were carried out on a Wickstead single-lever machine,* reading up to 10,000 lbs. by intervals of 1 lb. (with vernier); the strain being noted by means of a Ewing extensometer,* whilst the diameters of the three specimens were measured horizontally and vertically at intervals of on

* For illustrations and detailed descriptions of apparatus, see "Strength of Materials," by J. A. Ewing. F.R.S., pp. 62, 76.

inch and the mean value taken for each specimen. It was found that experiments on bending were more troublesome than those on tension, owing to sliding friction at the knife-edge supports. This, however, was completely overcome by the insertion of a rocking knife-edge at one end of the rod, as shown in Diagram I. The deflections were measured by a low-power microscope with a

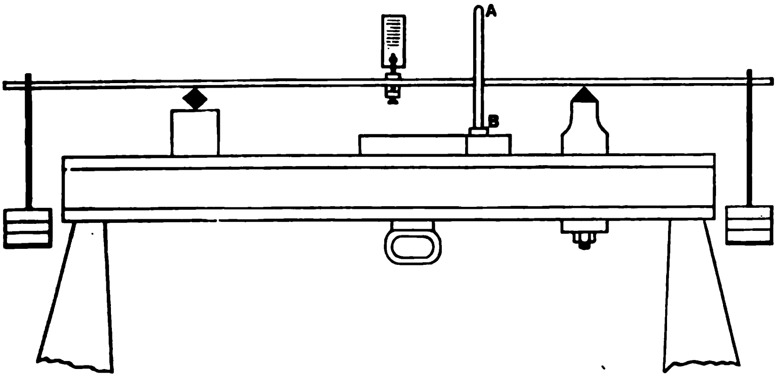


DIAGRAM I.
Micrometer Eyepiece is fixed to A B.

micrometer eyepiece reading on a glass millimetre scale attached to the middle of the rod under test.

The length of material used in bending was considerably greater than that used in tension, but the tension specimen was always cut from the middle of the rod, and dimensions were in all cases noted.

In the bending experiments it was of course necessary that there should be no shearing action in the portion of the rod between the knife-edges, and this result was obtained by suspending the load from overhung ends. In order to avoid wasting the material, iron pipes were fitted on to either end of the rod, and these pipes (not shown in the diagram) were made to carry the loads.

In the following tables of measurements—

l_1 = the length between the knife edges in inches.
l_2 = the overhung length at each end in inches.
W = the load in pounds hung from each end.

Bending Experiments.

SPECIMEN A.

Date.	Temperature.	l_1.	l_2.	W.	Deflection in mm.
19.2.00	...	36·07	15·08	15	[illegible]
20.2.00	...	36·09	15·27	15	[illegible]
20.2.00	...	36·07	15·26	15	10·70
24.2.00	63° F.	36·09	15·26	15	[illegible]
24.2.00	63° F.	36·14	15·24	15	[illegible]

The values of E in pounds per square inch obtained from these five experiments are respectively: 29·24; 29·31; 29·21; 29·22, and 29·23, each multiplied by 10^6.

The mean value is $29{\cdot}24 \times 10^6$.

Other constants for the specimen were: mean diameter (mean of 80 readings taken between the knife-edges) = 0·4984 inch.

Moment of inertia of section about a horizontal axis through the centre of area $= \frac{1}{330{\cdot}7}$ in (inches)^4.

SPECIMEN B.

Date.	Temperature.	l_1.	l_2.	W.	Deflection in mm.
26.2.00	63° F.	32·07	15·15	15	[illegible]
26.2.00	63° F.	32·06	15·19	15	[illegible]
27.2.00	62° F.	31·98	15·15	15	[illegible]
27.2.00	62° F.	31·98	15·16	15	[illegible]

Value of E: 29·74; 29·78; 29·77, and $29{\cdot}78 \times 10^6$.
Mean value for $E = 29{\cdot}77 \times 10^6$ lbs. per square inch.
Mean diameter (60 readings) = 0·4983 inch.
Moment of inertia of section = $\frac{1}{[illegible]}$ in (inches)^4.

SPECIMEN C.

Date.	Temperature.	l_1.	l_2.	W.	Deflection in mm.
8.3.00	62° F.	35·88	15·07	15	9·694
8.3.00	62° F.	36·04	14·99	15	[illegible]
9.3.00	61° F.	36·00	15·00	15	[illegible]
9.3.00	60° F.	36·00	15·00	15	[illegible]
13.3.00	60° F.	36·00	15·00	15	[illegible]
13.3.00	60° F.	36·00	15·00	15	[illegible]
13.3.00	60° F.	36·00	15·00	15	[illegible]

Values of E: 29·65; 29·49; 29·64; 29·67; 29·67; 29·66, and [illegible] $\times 10^6$.
Mean value for $E = 29{\cdot}63 \times 10^6$ lbs. per square inch.
Mean diameter (70 readings) = 0·5063 inch.
Moment of inertia of section = $\frac{1}{[illegible]}$ in (inches)^4.

[redacted]

Tension Experiments.

Used an 8-inch length from the centre of each rod.

Mean diameter of Specimen A = 0·4986 inch.
,, ,, Specimen B = 0·4982 ,,
,, ,, Specimen C = 0·5069 ,,

Loads are in pounds.

SPECIMEN A.

Temperature = 54° F. Date, 27.4.00.

Extensometer Readings.

Load.	On.	Off.	On.	Off.	Mean.
0	224	225	225	225	224·8
500	260	262	260	263	261·2
1000	296	300	297	299	298·0
1500	329	334	330	335	332·0
2000	364	369	365	369	366·8
2500	399	402	400	403	401·0
3000	433	439	434	439	436·2
3500	470	472	470	472	471·0
4000	503	508	505	508	506·0
4500	539	541	540	542	540·5
5000	575	577	576	578	576·5
5500	610	610	611	611	610·5
6000	645	645	646	646	645·5

Calibration constant (mean of 6 readings) = 3959.
Value of E calculated from the above = $29·64 \times 10^6$ lbs. per square inch.

SPECIMEN B.

Temperature = 61° F. Date, 7.5.00.

Extensometer Readings.

Load.	On.	Off.	On.	Off.	Mean.
0	300	299	299	298	299·0
500	332	333	336	332	333·3
1000	368	369	370	369	369·0
1500	401	404	403	404	403·0
2000	437	439	438	439	438·2
2500	471	475	472	474	473·0
3000	507	509	508	509	508·3
3500	540	542	541	542	541·2
4000	576	578	577	578	577·3
4500	610	611	610	611	610·5
5000	646	646	646	646	646·0

Creeping sets in at 5500 lbs.
Calibration constant (mean of 4 readings) = 3964.
Value of E calculated from the above = $29·86 \times 10^6$ lbs. per square inch.

SPECIMEN C.

Temperature = 55° F. Date, 26.3.00.

This specimen required 1000 lbs. to straighten it; readings therefore begin at this poin[t]

Extensometer Readings.

Load.	On.	Off.	On.	Off.	Mean.
1000	511	516	514	516	[illegible]
1500	543	547	546	547	[illegible]
2000	575	578	578	578	[illegible]
2500	606	609	608	609	[illegible]
3000	638	639	639	639	[illegible]
3500	669	670	669	670	[illegible]
4000	699	700	700	701	[illegible]
4500	730	731	730	732	[illegible]
5000	760	762	761	762	[illegible]
5500	791	793	792	793	[illegible]
6000	823	823	823	823	[illegible]

Calibration constant (mean of 9 readings) = 4342.
Value of E calculated from the above = $29·62 \times 10^6$ lbs. per square inch.

SPECIMEN C (repeated).

Temperature = 63° F. Date, 20.4.00.

Extensometer Readings.

Load.	On.	Off.	On.	Off.	Mean.
1000	331	334	331	333	[illegible]
1500	362	367	363	367	[illegible]
2000	395	398	395	399	[illegible]
2500	428	430	428	430	[illegible]
3000	460	461	460	461	[illegible]
3500	491	492	491	492	[illegible]
4000	522	523	522	524	[illegible]
4500	554	556	553	557	[illegible]
5000	585	588	586	588	[illegible]
5500	618	619	619	619	[illegible]
6000	650	650	650	650	[illegible]

Calibration constant (mean of 5 readings) = 4223.
Value of E calculated from the above = $29·57 \times 10^6$ lbs. per square inch.

The reason for repeating the measurements upon Specimen was that the author wished to find the sort of divergence t[hat] might be expected between results. The divergence found is l[ess] than $\frac{1}{8}$th per cent., and this difference is, at any rate, partly du[e]

[redacted]

the 8° F. difference in temperature, besides that due to experimental error.

Tabulated Results.

Material.	E by Bending. Mean.	E by Tension. Mean.	Difference.
A	29·24	29·64	0·40
B	29·77	29·86	0·09
C	29·63	29·60	0·03

Conclusion.

The two values of E given in the above table for Specimen C only differ by one part in a thousand, and the two amounts may therefore be taken as identical. The deduction from this fact is that for the Lowmoor iron used there is within the limits of these experiments no perceptible variation in the value for Young's modulus, whether determined by bending or by stretching; in other words, there is no internal sliding due to layers of any impurity that may be contained in the metal. In the case of Specimen B there is a difference of nearly one part in three hundred, and as a quantity such as this should be within the limits of observation (probably 1 in 500), the author concludes that the Swedish iron used, even though annealed, shows signs of the existence of sliding, through slag or other impurity that has been drawn out in the rolls. Lastly, in the case of Specimen A, which had been cold rolled, but had not afterwards been annealed, a divergence between the two values of E is found, which is distinctly marked, amounting as it does to about one part in seventy. Clearly, then, a small amount of sliding does take place in Swedish iron rod, but the effect is practically wiped out by annealing. The results of the experiments described in this paper may also be taken as showing that values of E obtained by bending and by tension differ slightly from each other, but that the usual custom in engineering—to make use of E as obtained by the one method in cases where the other form of stress is most in evidence—is justifiable. Such differences as are found may be regarded as indicating that the effect of slag does show itself in the way mentioned in the beginning of this paper. The preceding ex-

periments were all carried out in the Hopkinson wing of the Engineering Laboratory at Cambridge, and the author desires to thank Professor Ewing both for advice and for the use of the materials provided during the research.

APPENDIX.

The formula for determining the value of E from experiments on beams with overhung ends is given here:—

$$E = \frac{Ml_1^2}{8I\delta}\left(1 + \frac{4\delta^2}{l_1^2}\right).$$

Where deflection $= \delta$; $I =$ Moment of inertia; and $M = W.l_2 =$ the constant bending moment.

In the tension experiments the value of E was deduced by the method of least squares. The formulæ that were found by this method were, for the four experiments:—

1. $R - 226{\cdot}5 = 0{\cdot}06967\ L.$
2. $R - 299{\cdot}2 = 0{\cdot}06937\ L.$
3. $R - 453{\cdot}4 = 0{\cdot}06163\ L.$
4. $R - 260{\cdot}4 = 0{\cdot}06349\ L.$

Where $R =$ Mean extensometer reading and $L =$ Load in lbs.

OBITUARY.

The Rt. Hon. Lord Armstrong, whose many inventions earned for his name a world-wide fame, died on December 27, 1900, at his residence, Cragside, Rothbury, Northumberland. Born on November 26, 1810, William George Armstrong was the son of a merchant of Newcastle-on-Tyne. He was educated at Bishop Auckland, and chose the law as his profession, notwithstanding a bias towards scientific and mechanical subjects. Later, while still a member of a firm of Newcastle solicitors, he commenced his career as an inventor. In 1838, having long reflected on the enormous power available in the innumerable streams descending the hills of the North Country, he devised a hydraulic rotary engine, which he hoped might utilise some of the energy running so freely to waste. But finding that for many purposes—such as the operating of cranes on wharves—the reciprocating principle was superior to the rotary, he designed a crane in which cylinders and pistons effected every required motion. It was not till 1845, however, that opportunity arose for the realisation of his scheme, but before the end of 1846 the first hydraulic crane erected was at work on the quay at Newcastle. Meanwhile, in 1840, Armstrong published an account of his investigations on the "Electricity of Effluent Steam"—investigations which led to his invention of the "hydro-electric machine," which so greatly interested Faraday. By 1846 his discoveries and applications had attained such importance that he was in that year elected a Fellow of the Royal Society. Armstrong continued to erect hydraulic plants at various places in the country, using in every case the pressure of the town mains or the head of special reservoirs. In 1850 he introduced into his system the use of the well-known accumulator, which made hydraulic power capable of vastly wider adoption.

At the Elswick Works, then thoroughly established, but as yet wholly devoted to the manufacture of hydraulic machinery, certain experiments in gun-building were inaugurated. As a result, in 1856 Armstrong's first gun was produced. It was built by shrinking on to a steel barrel successive iron tubular shells; it was a breech-loader, and possessed polygrooved rifling. It fired a projectile of elongated shape and with ogival head with unexampled accuracy over an unprecedented range;

and so satisfactory proved its trials that Armstrong was appointed Engineer of Rifled Ordnance, was made C.B., and knighted. Within the seven years succeeding more than 3000 similar guns were added to England's armament. Unfortunately the continual recurrence of certain difficulties in the breech mechanism impelled the Government in 1863 to return to muzzle-loading guns. Sir W. Armstrong resigned his official position simultaneously. The same year he was president of the British Association at its Newcastle meeting. His address dealt with the then already threatening depletion of the British coalfields, and with the extravagant methods of coal users. When the Royal Commission on this same question was shortly afterwards ordered, Sir W. Armstrong was nominated to sit as a member.

Various honours fell to him about this time. He was in 1862 made an LL.D. of Cambridge, in 1870 a D.C.L. by Oxford, and in 1878 the Albert medal of the Society of Arts was awarded him. But there came to him a greater triumph when, in 1880, the Government re-adopted the breech-loading and polygroove rifling principles of Armstrong. The following year, in his capacity as president of the Mechanical Section of the York meeting of the British Association, he again called attention to the more efficient utilisation of natural sources of energy. He raised a hope that the development of the thermopile might lead to a wholesale utilisation of solar energy. He estimated that the heat received by an acre of ground in the tropics would, if wholly converted, yield mechanical energy at the average rate of 4000 horse-power. In 1882 he was elected president of the Institution of Civil Engineers, and was elevated to the peerage in 1887—the year after his unsuccessful parliamentary contest of Newcastle against Mr. John Morley. In 1897, when in his eighty-seventh year, he published an illustrated book, entitled "Electrical Movements in Air and Water," which discussed certain phenomena he had observed in his electrical experiments conducted fifty years previously. He received numerous foreign decorations. He was a Grand Officer of the Order of San Maurizio e Lazzaro of Italy, and a Knight Commander of the Orders of the Dannebrog of Denmark, of Charles III. of Spain, of Francis Joseph of Austria, of the Rising Sun of Japan, and of the White Elephant of Siam.

He was an original member of the Iron and Steel Institute, and in 1891 was awarded the Bessemer Gold Medal. In presenting the medal, the President, Sir Frederick Abel, dwelt upon the importance of Lord Armstrong's many scientific investigations bearing upon the properties of iron and steel, such as his experiments on the elasticity and the

first moving-point of iron and steel. Especially important was his work in connection with the tempering and treatment of steel, that had led to the introduction of the oil-hardening process.

Thomas Addyman died on February 26, 1901, at the age of forty-four years. He was the second son of Thomas Addyman of Belmont, near Harrogate, Yorkshire, leather merchant. He was educated at Dragon College, Harrogate, and afterwards at Wesley College, Sheffield. After leaving school in 1874 he entered the works of Hopkins, Gilkes, and Co., of the Tees Engine Works, Middlesbrough. He remained with that firm after the expiration of his apprenticeship until the year 1880, when he joined the firm of Frank Pearn and Co., of West Gorton, Manchester (which was converted into a private limited company in 1893, and of which he became a managing director), and the connection thus formed lasted until his death. He was elected a member of the Iron and Steel Institute in 1880.

Richard Attenborough died at his residence, Horton House, Northampton, on May 19, 1901, at the age of seventy-nine. He was one of the best known members of the family of London pawnbrokers of that name. He went at an early age to London from Northamptonshire to take part in his uncle's business, and subsequently retired to Reading, where he became a member of the Town Council and an officer in the Berks Volunteers. He twice contested the parliamentary borough on behalf of the Conservatives, at the general election of 1874 and the by-election of 1878, but was unsuccessful on both occasions. He afterwards moved to his native county, and at the time of his death possessed valuable iron mines in Northamptonshire and Lincolnshire. He was elected a member of the Iron and Steel Institute in 1898.

Robert Scott Burn died in Edinburgh on January 31, 1901, at the age of seventy-five. He was the author of a large number of technical handbooks, some of which maintained a steady sale during the last thirty-five years. The subjects dealt with included mechanics and mechanism, the steam-engine, building construction, and various branches of agriculture. He also wrote several works of a religious character, some of which were issued through the Religious Tract Society. He was elected a member of the Iron and Steel Institute in 1881.

Joseph Craven died in December 1900 at his residence, Broom Bank Mount, Glossop Road, Sheffield, at the age of seventy-two years. He was the eldest son of the late David Craven, who was for many years a successful building contractor. On the retirement of that gentleman the business was carried on by his three sons, Joseph, John, and Alfred, of whom only the youngest, Mr. Alfred Craven, now survives. Whilst in the building trade the three brothers carried out many large contracts, including Endcliffe Hall and several other large residences; but about thirty-five years ago they embarked upon a new venture, and put up a large works at Darnall for the building of railway waggons. Shortly before, they had executed the contract for some large engine works, and it was this which gave them the idea of entering into the waggon-building trade. The business thus established by the three brothers became a flourishing one, and at a later date its scope was extended to include carriage-building and wheel-making. Mr. Joseph Craven was actively associated with the business until about five years ago, when he retired. He was elected a member of the Iron and Steel Institute in 1884. As a member of the Reception Committee, he took an active part in organising the Manchester meeting of the Institute in 1899.

Edward Charles Darley died at the Beach Hotel, Chicago, on February 16, 1901, at the age of fifty-five, whilst undergoing an operation on his throat. He was well known among mechanical engineers both in Pittsburg and Chicago. At the time of his death he was Western sales agent for the Cahall boiler. For some time he was connected with Mr. James P. Witherow, of Pittsburg, and was well known as a blast-furnace engineer. He was the secretary of the Technical Club of Chicago, a member of the American Society of Mechanical Engineers, and of the American Institute of Mining Engineers. He was elected a member of the Iron and Steel Institute in 1891.

Richard Day died at Bridlington on August 16, 1900. He was formerly a woollen manufacturer in Dewsbury, and retired from business some twenty years before his death. About that time he became largely interested in collieries, and was subsequently appointed director of the Soothill Wood Colliery Company, Limited, Batley, and chairman of the White Lea Colliery Company, Limited, Birstall, chairman of the Mablethorpe Gas Company, and was interested in ironworks and many

other companies in various branches of industry. He was elected a member of the Iron and Steel Institute in 1890, and regularly attended the meetings, having taken part in those in France, America, Belgium, Spain, and Sweden.

Edward Knapp Fisher died at Market Harborough in March 1901, at the age of seventy-four years. He was the founder of the Glendon Ironworks in Northamptonshire, for a number of years the largest establishment engaged in the pig iron industry in that county. He was the head of a well-known firm of land agents having an extensive business in the Midland counties. He was elected a member of the Iron and Steel Institute in 1871.

George Baker Forster, the eminent North Country mining engineer and coalowner, died on January 19, 1901, at his residence at Farnley Grove, Corbridge, near Newcastle-on-Tyne. He was the son of the late Thomas Emerson Forster, and was sixty-eight years of age. He was educated at Repton School, at St. Peter's School, York, and at St. John's College, Cambridge. He enjoyed a very large practice as a mining agent for royalty proprietors, including Lord Lonsdale, the Earl of Zetland, Lord Boyne, and many others. He was a member of several Royal Commissions, including the Royal Commission to inquire into the high price of coal in 1894. Mr. Forster was extensively consulted in all matters relating to mining arbitrations, and was in full work until his death. He was the first arbitrator appointed in 1875 after the boom in the coal trade, to settle wages, and he enjoyed the confidence both of masters and men. Joining the North of England Institute of Mining Engineers in 1857, of which he was president for three years, he was vice-chairman of the United Coal Trade, and also of the Northumberland Coalowners' Association from 1885 until his death. On the occasion of the Hartley Colliery accident in 1862, when 200 lives were lost, he was one of the leading men who conducted the explorations, and one of the first to reach the bodies of the unfortunate miners. He was a Justice of the Peace for the county of Northumberland, a member of the Institution of Civil Engineers, and a Fellow of the Geological Society. He was elected a member of the Iron and Steel Institute in 1883.

William Gill, who died at Wells, in Somersetshire, on January 20, 1901, at the age of fifty-seven, in his capacity as general manager of the

Orconera Iron Ore Company, did more than any one else to build up the iron ore trade of Bilbao. His elaborate memoirs on the Bilbao iron ore district, contributed to the Iron and Steel Institute in 1882 and 1884, are the standard works of reference on the subject. His early training was in connection with railway engineering on the Bombay and Baroda Railway. He subsequently entered the service of Mr. Robert Fairlie, and later on was engaged in railway construction in Russia, Brazil, Peru, and in other parts of the world. In 1880 he was appointed general manager of the Orconera Company. He was a member of the Institution of Civil Engineers. He was elected a member of the Iron and Steel Institute in 1881, and as local honorary secretary organised the highly successful meeting in Bilbao in 1896.

Alexander R. Miller died on January 23, 1901, at his residence, Glenlee, Hamilton, N.B., at the age of sixty. He was born in Coatbridge, and passed through all the grades of the iron trade until he became proprietor of the Little Globe Ironworks in Coatbridge. While in that town he was a member of the Town Council, and was also a bailie. He went to Motherwell in 1884, when he purchased a tinworks, which were converted by him into an ironworks and renamed the Globe Ironworks. Two or three years ago he was made a Justice of the Peace for the county of Lanark. He was elected a member of the Iron and Steel Institute in 1896.

Thomas Parkin Moorwood died on March 13, 1901, at the age of sixty-five years. He was head of the firm of Moorwood Sons and Company, Limited, of Harleston Ironworks, Sheffield. He had been engaged in the steel trade for about forty years, and his death removes a prominent figure from Sheffield industrial circles. He was born at Ecclesfield in 1835, and his early business career was spent at the Thorncliffe Ironworks of Newton, Chambers and Co. About 1860 he went to Sheffield, and in partnership with his brother-in-law, Mr. Thomas Watson, and the late Mr. Thomas Marshall, established the Harleston Works, Carlisle Street, East. The business carried on by the firm was that of engineers, ironfounders, stove-grate manufacturers, &c. One of the chief branches of the work has always been that of producing castings for use in the Sheffield trades, and the Harleston works have developed with those trades until now the foundry, in its capacity for turning out large castings, is one of the most important in the North of England. Both Mr. Marshall and Mr. Watson ceased their connection

with the firm, and for the last ten years the business has been entirely under the management of Mr. Moorwood, two of his sons being the chief members of the firm besides himself. Mr. Moorwood was a Conservative, but he did not take any part in public life. He was elected a member of the Iron and Steel Institute in 1894.

THOMAS OWEN died at Derby on January 27, 1901, at the age of forty-six years. He was a member of the Institution of Mechanical Engineers, and for the past twenty-five years had been permanent way inspector on the Midland Railway. He was elected a member of the Iron and Steel Institute in 1899.

CHARLES HENRY PUGH died on April 9, 1901, at his residence at Penns, near Birmingham, at the age of sixty-one years. He was originally a screw manufacturer, and carried on business at Rea Street, South Birmingham, but in 1892 he entered the cycle trade, and formed the Whitworth Cycle Co., which developed to such an extent that in 1896 it was amalgamated with the Rudge Co., thus forming the Rudge-Whitworth, Limited. He was also connected with the Palmer tire, and he was inventor of the jointless rim. He was elected a member of the Iron and Steel Institute in 1890.

WILLIAM RUSSELL, of the firm of Russell Brothers, coal and iron merchants, 30 Gordon Street, Glasgow, died in April 1901, at his residence, Lillypark, Carluke. He was a native of Slamannan, and commenced his business career in Wishaw. He was cashier of the firm of J. and J. Williams and Co., Excelsior Ironworks, up to 1879, when, along with other gentlemen, he founded the Pather Iron and Steel Company, in which company he was appointed secretary. He commenced the present business at Gordon Street in 1891, and was the secretary of the Camp Coal Company, Motherwell. He was elected a member of the Iron and Steel Institute in 1883.

ALBERT SCHMITZ, died June 19, 1900. He was for many years a member of the directorate of the firm of Friedrich Krupp. Born on April 26, 1841, at Eschweiler, he was educated in Cologne and in Berlin. In 1863 he entered the service of Friedrich Krupp of Essen. He had charge of these works in 1870, and of the Bessemer works, where he introduced some great improvements in the manufacture of Bessemer steel. He subsequently was entrusted with the reconstruction

of the crucible steel foundry, and in that department also introduced notable improvements. In 1894 he was appointed a member of the Board of Directors of the firm, and in that capacity he took a prominent part in the management of the whole of the cast steel works, as well as in the laying out of the new plant at Rheinhausen, and in the technical supervision of the various works of the firm in other districts, notably the Krupp steel works at Annen and the Krupp-Gruson works at Magdeburg-Buckau. He was elected a member of the Iron and Steel Institute in 1891.

THOMAS SPENCER, of the firm of John Spencer and Sons, of Newburn Steel Works, Newcastle-on-Tyne, died on April 12, 1901, in Brussels, after an illness of some months. He was the third and youngest son of the late John Spencer, the founder of the steelworks at Newburn, and was in his seventy-sixth year. He was possessed of much energy and business capacity, qualities which naturally had their influence in the development of the steelworks of this firm. He was known for his liberality, especially in connection with education and ecclesiastical objects. When the Bishopric of Newcastle was created he contributed £10,000, and recently he gave a similar amount towards the establishment of a residentiary canonry in Newcastle Cathedral. He also gave £15,000 towards the restoration of Hexham Abbey Church; and churches at Ryton, Consett, Easington, and Newburn, as well as numerous charities, received donations from him at various times. He was an original member of the Iron and Steel Institute.

PETER STEWART died suddenly at Inverness on July 3, 1900. He was born in Glasgow on August 11, 1834. He served an apprenticeship to W. Cook and Co., and acquired a knowledge of mechanical drawing under the late Mr. Robert Harvey, whom he succeeded as teacher of that subject in the Glasgow Mechanics Institution. After being a short time in the service of A. and W. Smith and Co., Mr. Stewart was appointed engineer to the Tharsis Sulphur and Copper Co., Ltd., a position he occupied for upwards of thirty years. He was elected a member of the Iron and Steel Institute in 1883.

JOHN GEORGE SWAN dropped dead in the grounds of his house, Upsall Hall, as he was on his way to church, on December 23, 1900. He was born at Walker-on-Tyne in 1839, and entered the offices of Bell Brothers, at Newcastle, about forty years ago. When quite a young

man he went to Middlesbrough as commercial manager of what was then a branch of the Newcastle firm in whose employ he was. In 1864, in connection with some others, he established the Cargo Fleet Ironworks, of which he was manager, until the concern was converted into a limited liability company. He was also interested in the Bearpark Coal and Coke Co., and was connected with the Weardale Iron and Coal Co. Formerly he was captain of the North Yorkshire Militia. He was a member of the North of England Institute of Mining and Mechanical Engineers, and an original member of the Iron and Steel Institute.

Thomas Tempest-Radford, of Kidderminster, died on May 16, 1901, at the age of sixty-six years. He had been prominently connected with the Stour Vale Ironworks for a long period, and he had held the position of chairman of Knight and Crowther, Limited, the company owning the concern, for several years. He was elected a member of the Iron and Steel Institute in 1897.

John T. Tannett, who died in January 1901, at the age of sixty-one, at West Burton, Aysgarth, was well known and esteemed in the industrial circles of Leeds. He was a member of the firm of Smith, Beacock, and Tannett. His father, the late Mr. Thomas Tannett, of Roundhay Lodge, was one of the promoters of the famous tool-making business carried on at the Victoria Foundry, or, as it was popularly known, the "Round Foundry," in Water Lane, Leeds, and Mr. John Tannett himself was associated with the undertaking for many years. He was elected a member of the Iron and Steel Institute in 1876.

Charles Thomson, of Calder and Govan Ironworks (William Dixon, Ltd.), died suddenly at his residence, Carfin House, on February 11, 1901, at the age of fifty-three. He went to Calder in 1873, and took an active part in the management of the great iron-smelting firm. He served his time as a mining engineer preparatory to this. He was a grand-nephew of William Dixon, of Govanhill, the founder of the firm. He was elected a member of the Iron and Steel Institute in 1894.

Charles Wood died at Middlesbrough on April 23, 1901. He was a native of Ipswich and was a schoolfellow of the late Mr. Jeremiah Head. He served his apprenticeship there as an engineer, after which he was engaged in engineering enterprises in Russia and India. Nearly

forty years ago he accepted the appointment of engineer at the T Ironworks, Middlesbrough, continuing in that position until three four years ago, when he commenced business at works which he est lished at Cargo Fleet, near Middlesbrough, where he manufactured kinds of railway appliances, particularly those connected with li railways. To his ingenuity and skill were due several inventi connected with the working of blast-furnaces, but he was best kn by his endeavours to utilise blast-furnace slag. He invented introduced slag wool and slag bricks. He was elected a membe the Iron and Steel Institute in 1874, and contributed the follow papers to the Proceedings:—"The application of toughened g to permanent ways," 1879; "The economical preparation of i for the Danks puddling furnace," 1873; "Further improvements blast-furnace hearths," 1875; "The progress of slag industries du the last four years," 1877; "Statistics respecting the production depreciation of rails, and notes on the application of wrought iron steel to permanent ways, with a description of a new kind of rail sleeper and clip-chair," 1878; "The utilisation of slag," 1873; " value of silicon pig to the ironfounder," 1885; and "The wrou iron permanent way laid upon the North-Eastern Railway," 1879.

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"Receptions des Délégués des Sociétés Techniques et Savantes à l'Occasion de l'Exposition de 1900." Paris. 1900.	The Secretary, Société des Ingénieurs Civils de France.
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Title.	By whom Presented.
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"Weitere Fortschritte in der Verwendung der Hochofengase zur unmittelbaren Krafterzeugung." (Reprinted from "Stahl und Eisen," Nos. 9 and 10, 1901.)	E. Schrödter.
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"Iron, Steel, and Cast Iron as Materials for Bridge Construction." [In Russian.]	F. J. R. Carulla.
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City and Guilds Institute.
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Institution of Mechanical Engineers.
Institution of Mining and Metallurgy.
Institution of Naval Architects.
Royal Artillery Institution.
Royal Institute of British Architects.
Royal Institution.
Royal Society.
Royal Statistical Society.
Royal United Service Institution.
Society of Arts.
Society of Chemical Industry.
Society of Engineers.
University College.

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Engineering Society (Leeds).
Hull and District Institution of Engineers.
Institution of Engineers and Shipbuilders in Scotland.
Liverpool Engineering Society.
Manchester Association of Engineers.
Manchester Geological Society.
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Merchant Venturers' Technical College (Bristol).
Mining Institute of Scotland.
North-East Coast Institution of Engineers.
North of England Institute of Mining and Mechanical Engineers.
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South Wales Institute of Engineers.
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West of Scotland Iron and Steel Institute.

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Geological Survey of New South Wales.
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ted States.

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American Association for the Advancement of Science.
American Foundrymen's Association.
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American Iron and Steel Association.
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Franklin Institute.
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Ordnance Office, War Department.
School of Mines, Columbia College, New York.
Smithsonian Institute.
United States Geological Survey.

tria.

K.K. geologische Reichsanstalt.
Oesterr. Ingenieur- und Architekten-Verein.

;ium.

Association des Ingénieurs sortis de l'École des Mines de Liége.
Ministère de l'Intérieur.

ıce.

Comité des Forges.
"Revue Maritime." Ministère de la Marine.

Société d'Encouragement pour l'Industrie Nationale.
Société de l'Industrie Minérale.
Société des Anciens Élèves des Écoles Nationales d'Arts et Mét
Société des Ingénieurs Civils.
Société Scientifique Industrielle de Marseille.

Denmark.

Tekniske Foreningen.

Germany.

Königliche Bergakademie in Freiberg.
Königliche Technische Versuchsanstalt.
Verein Deutscher Eisenhüttenleute. (Journal "Stahl und Ei
Verein Deutscher Ingenieure.

Italy.

Reale Accademia dei Lincei

Sweden.

Jernkontoret

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"British Fire Prevention Committee."
"Citizen."
"Coal and Iron."
"Commerce."
"Contract Journal."
"Colliery Guardian."
"Electrician."
"Electrical Engineer."
"Engineer."
"Engineer and Iron Trades Advertiser."
"Engineering."
"Engineers' Gazette."
"Feilden's Magazine."
"Hardwareman."
"Hardware Trade Journal."
"Invention."
"Iron and Steel Trades Journal."
"Iron and Coal Trades Review."
"Ironmonger."
"Iron Trade Circular."
"Machinery Market."

"Marine Engineer."
"Mechanical Engineer."
"Mechanical Progress."
"Petroleum Review."
"Phillips' Monthly Register."
"Plumber and Decorator."
"Practical Engineer."
"Railway World."
"Science and Art of Mining."
"Shipping World."
"Statist."
"Steamship."
"The London Technical Education Gazette."
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"Indian Engineering."

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"American Machinist."
"American Manufacturer."
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"Engineering and Mining Journal."
"Engineering Magazine."
"Engineering News."
"Iron Age."
"Iron Trade Review."
"Letter of the Anthracite Coal Operators' Association."
"Metallographist."
"Mines and Minerals."
"Railroad Gazette."
"Report of Proceedings of the Master Car Builders' Association."
"Tin and Terne."

Austria.

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"Bulletin de l'Union des Charbonnages de Liége."
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"Revue Universelle des Mines."

France.

"Annales des Mines."
"L'Echo des Mines."
"Le Génie Civil."
"Le Mois Scientifique et Industriel."
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Germany.

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"Chemiker Zeitung."
"Glückauf."
"Verein Deutscher Eisen- und Stahl-Industrieller."
"Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussisch Staate."
"Zeitschrift für praktische Geologie."
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SECTION II.

NOTES ON THE PROGRESS OF THE HOME AND FOREIGN IRON AND STEEL INDUSTRIES.

CONTENTS.

In the preparation of these Notes the Editor has been assisted by E. J. Ball, Ph.D. and H. G. Graves, Assoc. R.S.M.

IRON ORES.

CONTENTS.

I.—*OCCURRENCE AND COMPOSITION.*

Ore Deposits.—R. Beck * has written an exhaustive treatise ore deposits, in two volumes. The classification of ore depo adopted by the author is based exclusively on their mode of ori His two main classes are subdivided in the following manner: *Primary deposits:* Group A.—Syngenetic deposits or deposits forn contemporaneously with the surrounding rock. 1. Magnetic depo such as magnetite in orthoclase porphyry. 2. Ores as sediment rocks, either those nearly in the same condition as at the tim their deposition, such as bog iron ore, or those that have been jected to metamorphic processes, such as the magnetite ores of crystalline schists. Group B.—Epigenetic deposits or deposits forn subsequently to the surrounding rock. 1. Mineral veins or lo 2. Epigenetic deposits that are not of the form of veins; (*a*) epigen ore beds, or deposits mostly of distinctly stratified character, forn essentially by an impregnation of non-calcareous rocks; (*b*) epigen ore masses, or deposits formed by a metasomatic saturation of careous rock, such as calamine deposits in limestone; (*c*) cont metamorphic deposits, or beds and masses formed at the side plutonic intrusive rocks, such as contact-metamorphic magnetic ores; (*d*) metalliferous deposits filling cavities or masses formed

* *Lehre von den Erzlagerstätten*, Berlin: Borntraeger, 1900 and 1901.

a simple filling of pre-existing cavities, such as pisolitic iron ore. II. *Secondary deposits*, or deposits formed from the destruction and re-deposition of primary deposits: 1. Deposits formed by chemical action; 2. Deposits formed by mechanical action. The first part carries the subject up to the end of mineral veins. All the more remarkable deposits are concisely described, and careful references are given to the literature of the subject.

In the second volume, the consideration of mineral veins is brought to a conclusion, and the remainder of the volume is devoted to (1) non-vein-like epigenetic ore deposits enclosed in stratified rocks; (*a*) epigenetic ore beds; (*b*) epigenetic ore masses; (*c*) contact-metamorphic ore deposits, and (*d*) metalliferous filled-in cavities; (2) secondary or alluvial deposits; and (3) general hints on prospecting for ore deposits.

The various theories of the genesis of mineral veins are discussed under four heads: (*a*) The congeneration theory, which is now only of historical interest; (*b*) the theory of deposition from above; (*c*) the lateral secretion theory; and (*d*) the theory of ascension or deposition from below. The theories of the last class assume that the materials filling fissures and impregnating the rock rise from unknown depths either in a molten state (injection theory), in the form of gases and vapours (sublimation theory), or dissolved in more or less hot water also containing gases (thermal theory). It is impossible, the author shows, to explain the genesis of all veins by a single theory. In the case of bedded deposits of sulphide ores, the mode of origin has long been a matter of controversy. On the one hand, there is the precipitation theory, according to which beds composed of sulphide ores, often of considerable thickness, have been deposited on the bottom of the ocean. On the other hand, endeavours have been made to explain such deposits by assuming that ordinary sediments have been impregnated with ore by a subsequent infiltration of ore solutions from vein fissures. The author regards the latter hypothesis as being the more probable in most cases.

The Origin of Iron Ores.—A number of tables are given showing the chemical composition of spathic iron ores, clay ironstones, limonites and hæmatites, chiefly of English origin, and it is held that the majority of these iron ores are of the nature of alteration pseudomorphs. They have subsequently undergone various degrees of metamorphism, which may or may not have obliterated the original

structure of the parent rock, while retaining, at the same time, most of the impure earthy ingredients of that rock. The comparative ease with which iron compounds undergo chemical transformations, and the inexhaustible supply of iron-bearing minerals diffused through the rocks of the earth's crust, render it easy to understand the causes of the concentration of iron ores into workable deposits, as well as their wide distribution and variable quality.*

J. H. L. Vogt † brings evidence in confirmation of his theory that the deposits of titaniferous iron ore, which occur in primary formations, are in reality basic segregations, which have been formed under pressure, and gives the result of his recent investigations of several deposits in Norway. In one instance, at Spisholdt, near Krekling, samples of titaniferous magnetite were found to contain a strikingly large amount of apatite, to the extent of 10 per cent., in crystalline form.

The formation of bog iron ores is discussed by J. M. van Bemmelen,‡ with special reference to the deposits in Holland.

The Occurrence of Anthracite in Hæmatite.—In the Devonian hæmatite mined at Dillenburg, Nassau, anthracitic inclusions occur over a length of 1800 feet. They are dispersed uniformly in the direction of the dip from the outcrop down to the lowest depth (390 feet) reached. L. Loewe § considers that the ferruginous waters, that altered the original limestone beds into hæmatite, held in suspension organic substances which were precipitated with the iron, and eventually became anthracite.

Iron Ore in Cumberland.—W. E. Walker ‖ describes the hæmatite mining in Cumberland, and discusses the future supplies of ore in the district. In his opinion the amount of ore yet to be discovered and worked is greater than that produced in the past.

Iron Ore in Austria.—J. Lowag ¶ describes the iron ore deposits of Freudenthal in Austrian Silesia. The mines were worked in pre-

* *Colliery Guardian*, vol. lxxx. pp. 807, 855.

† *Zeitschrift für praktische Geologie*, 1900, pp. 370-382.

‡ *Archives Néerl. des Sciences exactes et naturelles*, vol. iv. pp. 19-91; *Zeitschrift für anorganische Chemie*, vol. xxii. pp. 313-379.

§ *Zeitschrift für praktische Geologie*, 1900, pp. 341-342.

‖ Paper read before the Whitehaven Scientific Association, February 12, 1901; *Colliery Guardian*, vol. lxxxi. p. 461.

¶ *Montan-Zeitung*, vol. viii. No. 5.

[redacted]

historic times. Originally the ironworks were situated at the fortified town of Freudenthal, on the site of the present villages of Altstadt and Neudörfel, where traces of slag are still to be found, and the ore was brought from the hills at Kleinmohrau and Neuvogelseifen. The history of the various ironworks is traced up to the year 1860, when the scarcity of wood for charcoal-making rendered it necessary to shut down the blast-furnaces. The manufacture of wire, wire rods, and chains continued, however, until 1896. The ore smelted consisted of magnetite with red hæmatite and specular iron ore. The proportion of iron varied from 28 to 62 per cent. The ore occurs in bedded masses, enclosed in Lower Devonian chlorite schist. The mines have been worked only to a very slight depth, and with the improved railway communication it might be a remunerative undertaking to re-open them.

J. Blaas * describes the occurrence of iron ore in the Stubai valley in the Tyrolean Alps. The ore occurs in beds of 3 to 4 yards in thickness, but an accurate survey of the extent of the deposits has still to be carried out. It is thought that the mining of these deposits would prove remunerative.

F. Ryba † confirms Vogt's hypothesis that the chrome iron ore that occurs in eruptive peridotites, or in the serpentines derived from them, is a primary product of magmatic differentiation. At Kraubat, in Upper Styria, chrome ore occurs of the following composition:—

SiO_2.	MgO.	CoO.	Fe_2O_3.	Al_2O_3.	Cr_2O_3.
4·3	9·7	6·4	9·1	13·7	56·2

The ore occurs scattered irregularly in a rock, whose principal constituents are olivine and chromite.

Iron Ore in France.—Coignard ‡ gives the results of analyses of siliceous carbonate of iron from Saint-Roman, Gard (36·10 per cent. of iron and 3·30 per cent. of manganese); of brown hæmatite from Cambo-les-Bains, Basses-Pyrénées (42·4 per cent. of iron, 0·23 per cent. of phosphorus, and 23·20 per cent. of silica); of limonite from Saint-Julien de Valgalgues, Gard (35·2 to 48·6 per cent. of iron); and of limonite from Mende, Lozère, from Saint-Etienne de Valdonnez, and from Pellet, Gard.

* *Zeitschrift für praktische Geologie*, 1900, pp. 369–370.
† *Ibid.*, 1900, pp. 337–341.
‡ *Annales des Mines*, vol. xviii. p. 489.

Iron Ore in Lorraine.—H. Ansel* gives a detailed description of the oolitic iron ore formation of German Lorraine. The subject is dealt with under the following heads:—(1) Geographical position; (2) Geology; (3) Petrography of the minette formation; (4) The various beds; (5) Faults; (6) Extent of the beds; (7) Available supply of ore; (8) The genesis of the iron ore beds. The paper is illustrated by a map on a scale of 1 to 150,000, showing the principal faults between Fentsch and Gorze, by six sections of shafts and bore-holes, and by three sections of strata. The author shows that the Lorraine minettes are of marine origin, dating from the Lower Dogger period. There is enough ore to last, with an annual output of 8,000,000 tons, for 250 years.

G. Rolland † discusses the genesis of the beds of oolitic iron ore in Lorraine. He shows that the oolitic iron ores are of a sedimentary nature and of a Continental origin.

Iron Ore in Luxemburg.—The following are some analyses of Luxemburg iron ores: ‡—

	I.	II.	III.	IV.	V.	VI.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Fe_2O_3	47·91	58·10	56·29	38·49	56·49	25·95
Met. Fe.	33·24	40·67	39·49	27·63	39·20	18·17
Mn_3O_4	0·80	0·52	0·54	0·36	0·51	0·29
Met. Mn	0·38	0·37	0·39	0·26	0·36	0·20
SiO_2	6·84	7·54	13·35	41·96	16·10	8·48
Al_2O_3	5·23	4·74	6·10	4·57	6·43	2·28
CaO	16·34	7·68	6·44	4·93	5·30	33·32
P_2O_5	1·80	2·27	2·31	1·66	1·88	1·09
P	0·80	0·99	1·00	0·72	0·81	0·53

Nos. I. and II. are from the Rumelange-Dudelange basin; Nos. III. and IV. from the Esch field; and Nos. V. and VI. from that of Differdange-La Madelaine.

Iron Ore in Bosnia.—According to F. Poech, ‖ the iron ore resources of Bosnia are very considerable, the most important mines being those of Vares, near Sarajevo, where a series of alternations of red and brown manganiferous hæmatites and spathic ores, included

* *Zeitschrift für praktische Geologie*, 1901, pp. 81-94.
† *Comptes Rendus de l'Académie des Sciences*, February 18, 1901.
‡ *Stahl und Eisen*, vol. xx. p. 1266.
‖ "L'Industrie Minérale de Bosnie-Herzégovine."

between old crystalline schists and triassic limestones, are worked in open casts. The deposits measure from 200 to 330 feet across, and are estimated to yield 10,000,000 tons of ore without subterranean mining. The ore broken in the workings is lowered by an inclined plane 2296 feet long with a fall of 820 feet to the smelting works. The output for 1900 will be about 130,000 tons, about 50,000 tons being exported partly through Metkovic to the Trieste blast-furnaces, and partly by the northern railways to works in Hungary and Austria, while the remainder supplies the local furnaces. One high bloomary furnace still remains at Stari Madjau, in the north-west of the country.

Iron Ore in Elba.—V. Sevieri * gives the results of the analyses of a number of cargoes of iron ore from Elba. The total iron contents varied from 59·64 to 64·01 per cent., ferric oxide from 76·20 to 91·44, ferrous oxide from 0·68 to 10·20, silica from 4·01 to 9·78, alumina from 0·39 to 1·42, lime from 0·41 to 0·93, manganese from a trace to 0·70, phosphorus from 0·028 to 0·056, arsenic from a trace to 0·021, sulphur from 0·035 to 0·065, and loss on ignition from 3·51 to 5·69 per cent.

Iron Ore in Norway.—H. C. Carpenter † gives a résumé of J. H. L. Vogt's conclusions regarding the possibility of an iron industry in Norway, and the erection of blast-furnaces at Ofoten to deal with the Kiirunavaara ore.

Iron Ore in Roumania.—According to P. Poni, ‡ iron ore occurs in Roumania in workable deposits at several localities. The principal deposits are the magnetites between Podeni and Obirsa, the limonite beds on the western flanks of the Bahna Mountains and on Mount Dirmoxa, and the red hæmatites of the Suceva district.

Iron Ore in Russia.—The fear, to which reference has several times been made in these abstracts, that the iron ore deposits of the Krivoi Rog district were relatively approaching their end, appears now to be unfounded. In 1897 it was thought there were about 32,000,000 tons of ore left; in 1898 this quantity was estimated at

* *Rassegna Mineraria*, vol. xiv. pp. 101-102.
† *Engineering and Mining Journal*, vol. lxx. p. 372.
‡ *Annales Scientifiques de l'Université de Jassy*, 1900, pp. 15-148.

55,000,000 tons; and in 1899 the estimate had risen to 90,000,000 tons, new ore deposits having been repeatedly opened up. It is now believed that the iron industry of South Russia will be served by these deposits for the next thirty years.*

A large number of analyses of Russian iron ores are published by Neumark.† These are arranged according to districts. Seventeen analyses are given of ores from South Russia. These yielded:—

	Per Cent.
Iron	29·65 to 52·45
Manganese	0·19 ,, 2·30
Phosphorus	3·95
Copper	0·03
Silica	8·60 to 35·95
Alumina	0·35 ,, 13·86
Lime	0·41 ,, 15·42
Magnesia	2·14
Sulphur	0·28
Water	15·24
Loss on ignition	12·72

Of ores from the Krivoi Rog district eight analyses are given. These are as follows:—

	Per Cent.
Iron	46·54 to 66·00
Manganese	0·10 ,, 0·24
Phosphorus	0·01 ,, 0·04
Silica	3·73 ,, 26·00
Alumina	0·70 ,, 4·56
Lime	0·50 ,, 2·67
Magnesia	1·39
Sulphur	0·36
Water	5·00
Loss on ignition	5·80

Next on the list are Kertch ores. These are divided into "Light" and "Dark." The former contain about 43 per cent. of iron, and under 1 per cent. of manganese; while the "Dark" ores contain about the same percentage of iron, but up to 5·63 per cent. of manganese. Both varieties contain from 1 to 2 per cent. of phosphorus. Only two ores are given from Central Russia. These contained about 50 per cent. of iron. With regard to the Ural district, analyses are given of clay ironstones, magnetites, brown iron ores, manganese ores, and chrome iron ores. The manganese ores contain from 52 to 58 per cent. of manganese and 3·5 to 7·8 per cent. of iron, with but little

* *Stahl und Eisen*, vol. xx. p. 861. † *Ibid.*, vol. xxi. pp. 64–66.

phosphorus or sulphur. The following are the analyses of the chrome iron ores :—

	Per Cent. I.	Per Cent. II.
Chromium	23·33	32·40
Iron	7·8	...
Silica	13·8	6·8
Alumina	7·3	14·7
Lime	3·9	0·5
Magnesia	21·1	15·8
Sulphur	trace	...

No. II. contained 0·07 per cent. of manganese.

Analyses are also given of clay ironstones, brown iron ore, and limestones from Poland.

Iron Ore in Spain.—The following analyses of Spanish red hæmatite are published by E. F. Dürre : *—

1. *Asturian Ores Smelted at Trubia.*

	Quiros.	Quiros.	Castañedo.
Ferric oxide	79·54	74·40	70·58
Silica	14·00	16·20	20·84
Alumina	1·60	2·50	1·58
Lime	0·62	2·50	2·26
Magnesia	trace	trace	0·51
Manganese	0·80	trace	0·11
Sulphur	0·70	0·41	0·43
Phosphorus	0·48	0·05	1·52
Loss on ignition	2·86	3·40	...

2. *Ores from Almeria, South of Spain.*

Silica	5·55	10·33
Ferric oxide	88·08	83·01
Alumina	1·83	2·24
Lime	1·50	0·83
Magnesia	2·21	2·58
Phosphoric anhydride	0·11	0·21
Loss on ignition	1·60	1·50

H.M. Consul at Corunna has forwarded a report to the Foreign Office on the mining industry of Galicia.† The most important iron

* *Die Hochofenbetriebe am Ende des XIX. Jahrhunderts*, Berlin, 1901, p. 12.

† *Board of Trade Journal*, vol. xxxi. pp. 292–293.

mines exist in the northern part of the province of Lugo, in the neighbourhood of Vivero and Rivadeo. In the first of these places some mines were acquired by a German company with offices in London, who constructed an aërial tramway for the purpose of conveying the ore to a quay on the west side of the Bay of Vivero. It appears that the ores, which are phosphoric, contain 50 per cent. of iron. In the autumn of 1900 the first shipment was made. The phosphorus is utilised for the manufacture of manure. Calculations forecast that for the current year the extraction will be very nearly 125,000 tons, which, it has been arranged, will be transported to Rotterdam. At this rate of exhaustion the mines have a long life before them, since it is estimated that the deposit is 5,000,000 cubic metres in extent, or equal to 15,000,000 tons in weight. At Rivadeo, also, important works have been started by a Bilbao company, on a rich and extensive mineral zone, which contains about the same proportion of mineral as the Vivero deposit. A mountainous district in the south-eastern part of Lugo, called El Incio, and favourably known to the ancients as a mineral producer, contains a deposit giving from 57 to 62 per cent. of pure iron. The extent of the mineral occurrence is such that it is quite impossible for one company to work it alone; and its exploitation has hitherto been prevented by the fact that there are no advantageous means of transport at hand. A survey for a mineral line is now being carried out, and when the railway is completed an extensive and important mineral industry should spring up.

F. D. Adams * describes the iron ore deposits of Bilbao.

J. A. Jones † reviews the iron ore prospects in the provinces of Lugo and Leon, and in the Asturias.

Iron Ore in Switzerland.—A. Heim ‡ describes the iron ore deposit of Gonzen. The mines are no longer in operation, and the ore, which hitherto has been regarded as belonging to the Upper Dogger, is shown to be of Upper Jurassic age. The ore, which consists of hæmatite and magnetite, contains 50 to 60 per cent. of iron. It contains particles of iron pyrites, and is accompanied by manganese ore. About one-seventh of the deposit has been excavated, and about 1,500,000 tons of ore could be extracted.

* *Transactions of the American Institute of Mining Engineers*, Montreal Meeting.
† *Iron and Coal Trades Review*, vol. lxii. p. 705.
‡ *Vierteljahrsschrift der Nat. Gesellschaft in Zürich*, vol. xlv. pp. 183-198.

Iron Ore in India.—T. H. Holland * discusses the geology in the neighbourhood of Salem, Madras Presidency, and gives a number of analyses of ores which contain, on the average, 43·8 per cent. of magnetite and 33·2 of hæmatite.

Magnetic Iron Sand on the St. Lawrence.—J. Obalski † gives some notes on the magnetic iron ore sand found on the north shore of the St. Lawrence. In 1867 a company was formed to build eight bloomary furnaces. The ore was smelted with charcoal, and most of the product went to the United States; but in 1875 it was subjected to the higher tariff of bar iron, and the works had to shut down. The most important points at which the ore occurs are Natashquan, Moisic, and St. Jean. Probably the best way to treat the ore would be to dry it and pass it through magnetic concentrators. From 40 to 60 per cent. of black sand would thus be obtained.

Iron Ore in British Columbia.—According to H. M. Lamb,‡ the production of iron ore in British Columbia has not exceeded 2000 tons annually, and is mainly derived from two places, the Glen Iron mine, near Kamloops, and the mines on Texada Island. Other more or less extensive deposits have been found at Sooke, Chemainus, and Barclay Sound, on Vancouver Island; at Rivers and Knight Inlets, on the mainland; on the Queen Charlotte Islands; and in several places inland in the districts of Similkameen and Cariboo. On Texada Island the ore mass is an irregular contact mass between limestone and granite, 20 to 25 feet in width, and the ore contains up to 69 per cent. of iron. Analyses of ore from a partly explored deposit on Sarita River in Barclay Sound show 64 to 69 per cent. of iron, with traces up to 0·02 of sulphur and 0·003 to 0·01 of phosphorus. The geology of the various deposits is briefly sketched, and some illustrations are given.

Iron Ore in Georgia.—S. W. M'Callie § gives some notes on the red fossil iron ores of Dade, Walker, and Chattooga counties in Georgia. They occur in one or more beds near the centre of the Rockford formation, of Silurian age, which corresponds to the Red Mountain or Clinton formation in Alabama. As a rule, the bottom

* *Memoirs of the Geological Survey of India*, vol. xxx. pp. 111–115.
† *Transactions of the American Institute of Mining Engineers*, Montreal Meeting.
‡ *Engineering Magazine*, vol. xx. pp. 399–407.
§ *Engineering and Mining Journal*, vol. lxx. pp. 757–758.

bed yields the best ore, and the average thickness is about 3 feet. The ore is worked open cast when the cover does not exceed 10 feet; otherwise mining is resorted to. During part of last year the output amounted to about 600 tons daily.

A preliminary report has been published * on the iron ores, mainly limonite, of Polk, Bartow, and Floyd counties in Georgia. Maps and geological sections are appended.

Iron Ore in New Jersey.—Attention is called to the extensive iron ore resources of New Jersey, which are not only large and are being steadily worked, but new additions in the way of fresh discoveries are constantly being added to them. To a great degree they have been overshadowed during recent years by the huge deposits of the Lake Superior and the Alabama districts. Several of the mines now working are mentioned, and some of them at least have been developed to such an extent that their available reserves are now larger than they ever have been. Much of the country between producing mines has never been properly explored, or has only been touched by means of shallow workings, notably between the Mount Hope, Ringwood, and Sterling mines. Development along more modern lines is urgently called for to bring the State into the ranks of the foremost producers.†

Limonite in Pennsylvania.—According to T. C. Hopkins,‡ there has been renewed activity during the past year in the mining of limonite ores of Pennsylvania. This ore is widely distributed in the State, but the only deposits worked are in the Cambro-Ordovician limestones and slates. As a rule, the ore has not been worked to greater depths than 80 or 90 feet on account of water, but borings have shown that the ore is much deeper in places, and occasionally it extends over large areas. At the Scotia mines in Nittany Valley, for instance, over a hundred acres are worked. As a rule, the ore is treated in log washers, but hand-picking and jigs are sometimes used.

The Menominee Iron Ore District.—According to W. S. Bayley,§ the ore-producing rock of the Menominee district constitutes a

* Bulletin No. 10, *Geological Survey of Georgia*, Atlanta, Georgia, p. 190.

† *Iron Age*, November 29, 1900, pp. 21-22.

‡ *Mines and Minerals*, vol. xxi, pp. 97-100.

§ *Proceedings of the American Association for the Advancement of Science*, vol. xlix, pp. 189-190.

trough between rims of basic volcanic rocks on the south and granites and gneisses on the north, of Archæan age. Between these lie two series of Huronian rocks separated by an unconformity, and they are covered unconformably by Lake Superior sandstone. The ore formations are alternating beds of jasper, hæmatite, and quartzites, and mainly occur in the Upper Huronian, instead of in the lower series, as in the Marquette region.

The United States Geological Survey have published a geological map * on a scale of 1 to 62,500, with sections showing the geological relations of the Menominee iron ore district.

Iron Ore in Wyoming.—H. M. Chance † describes the iron ore deposits of Hartville, Wyoming. The ore is mainly hæmatite, low in phosphorus, and it occurs in lenticular deposits running north-east and south-west. Four large bodies have been developed, and there are indications of numerous other deposits. Most of the district is covered by 100 to 200 feet of quartzite, lying on the upturned edges of the slates in which the ores occur and are exposed by erosion. Secondary or replacement deposits are common, but do not appear to be of value. Average analyses of the hard red ore, locally known as blue ore, and of the soft ore show—

	Fe.	SiO_2.	P.
Hard ore	66·13	2·90	0·038
Soft ore	59·99	8·92	0·010

Iron Ore in Madagascar.—L. Pelatan ‡ describes the mineral resources of Madagascar. Gold and iron are the only metals widely distributed. The most remarkable iron ore deposits occur (1) at the north and east of Tananarive, in Imerina; (2) on the western slope of Ankaratra; and (3) in the south of Cetsileo. Some of these deposits have been actively worked in the past, and are still the object of primitive operations by the natives.

Manganese Ore in Brazil.—A large manganese ore deposit has lately been discovered near Ouro Preto, in the State of Minas Geraes. Analyses of samples taken from different parts of the vein give an average of 59 per cent. of manganese, with no phosphorus, and a very low percentage of iron. As the purest ore yet exported from Brazil

* "The Menominee Special Folio of the Geologic Atlas."
† *Transactions of the American Institute of Mining Engineers*, Montreal Meeting.
‡ *Revue Universelle des Mines*, vol. lii. pp. 270–312.

gives only an average of 52 per cent. of manganese, the value of t new discovery can easily be seen.*

Chrome Iron Ore in Greece.—One of the oldest minerals wor and exported from Greece is the chrome iron ore of the mines Bourdaly, in the province of Tharsala. These mines, which w discovered in 1870, are situated about 20 miles from the battlefiel Velestino, in the Kassidiari ranges. The annual production is al 3000 tons, which realises 70 francs per ton. The ores are mo shipped to Austria, and are employed in the manufacture of fe chromium. The mineral presents itself in compact masses in a white earth, sometimes greyish, and in contact with serpentine. Qu and schist are somewhat rare. An analysis of the ore gives—

Cr_2O_3.	Fe_2O_3.	Al_2O_3.	SiO_2.
32·3	41·0	16·0	8·0

Since 1867 other important discoveries of chrome iron ore l been made in the Pelion Ranges, close to the famous silver mine Kissos, in the Island of Eubœa, near the Bay of Karietos, in the t of Calchis, capital of Eubœa Island, and in the island of Tinos, which concessions have been asked.†

Nickel Ore.—The consumption of nickel has of recent years sh a considerable increase. The greater portion of the ore require obtained from New Caledonia, where it occurs in masses. Most the German deposits are poor and the ore difficult to smelt. It however, reported ‡ that a rich nickel ore deposit has been discove at Frankenstein, in Silesia. Another rich deposit is that at Versöhnung mine, in Hesse.

F. Danvers Power § describes the deposits of nickel, cobalt, chromium ores in New Caledonia.

Recent Researches on Meteorites.—R. T. Baker ‖ describe new meteorite found in January 1900 near Bugaldi, Coonabarabi New South Wales. It is a siderite, and shows Widmannstätten figu Apparently it is a recent fall.

* *Mining Journal*, vol. lxxi. p. 161. † *Ibid.*, vol. lxxi. p. 288.
‡ *Der Gnom*, November 24, 1900.
§ *Transactions of the Institution of Mining and Metallurgy*, vol. viii. pp. 426-47
‖ Paper read before the Royal Society of New South Wales, June 6, 1900.

E. von Fellenberg* describes the meteorite from Rafrüti in the Emmenthal, Canton Bern, Switzerland. It is a fragment of a large ellipsoidal iron found in 1886. It contains a high percentage of nickel, and also cobalt, phosphorus, and sulphur. It probably derived from a fall in October 1856.

S. Meunier † has analysed a meteorite which fell at Lançon, Bouches-du-Rhône, on June 20, 1897 at 8.30 p.m. Its specific gravity is 3·482. It contains 8·8 per cent. of grains attracted by the magnet, and containing 8·21 per cent. of nickel, 6·35 per cent. of pyrrhotine, 0·54 per cent. of chrome iron, and 32·10 per cent. of peridote. The insoluble residue, 52·21 per cent., consists of enstatite.

S. Meunier ‡ describes a mass of metallic iron said to have fallen from the sky in the Soudan on June 15, 1900. It showed on analysis 91·988 per cent. of iron, 7·15 nickel, traces of cobalt, 0·052 of ferrous sulphide, and 0·169 of ferrous phosphide, siliceous fragments and graphite. The metal is soft and malleable, with a specific gravity of 7·31, and does not show Widmannstätten figures on etching.

E. W. Cohen § describes the meteoric iron from Kokstad, Bethania, and Muchachos. The specimen of the Muchachos iron in the Vienna Museum was analysed, and is considered by the author to belong to a special group of ataxites.

E. W. Cohen ‖ describes the meteoric iron from Bethany, Great Namaqualand. It contained—

Fe.	Ni.	Co.	Cu.	C.	Cr.	S.	P.
91·07	8·18	0·63	0·03	0·01	0·02	0·04	0·06

Its mineralogical composition is 99·51 nickel iron, 0·39 schreibersite, 0·05 daubréelite, 0·04 troilite, and 0·01 lawrencite. Its specific gravity is 7·8408.

E. W. Cohen ¶ states that the "Kokstad" iron in the Vienna Museum gave the results under I. A larger mass (298 kilogrammes), supposed to be from Matatiela in the same district, which has been in the South African Museum since 1885, gave the results under II. Both are octahedral irons with lamellæ of medium width, but they show differences in structure which suggest that they do not belong to

* *Centralblatt für Mineralogie*, 1900, pp. 152–158.
† *Comptes Rendus de l'Académie des Sciences*, vol. cxxxi. p. 869.
‡ *Ibid.*, vol. cxxxii. pp. 441–444.
§ *Mittheilungen nat. Verein für Neuvorpommern und Rügen*, 1900, pp. 1–43.
‖ *Annals of the South African Museum*, 1900, vol. ii. pp. 21–29.
¶ *Ibid.*, vol. ii. pp. 9–19.

the same fall. It is proposed that the latter shall be known as the Matatiela iron.

	Fe.	Ni.	Co.	Cu.	C.	Cl.	P.	S.	Total.	Specific Gravity.
I.	91·21	8·01	0·63	0·02	0·03	0·05	0·22	trace	100·17	7·7876
II.	92·20	7·30	0·67	0·03	0·08	0·03	0·19	0·03	100·53	7·8084

E. W. Cohen * gives a summary of several of his recent papers on meteoric irons, of which the structure is compact or granular (ataxites). A comparison of the analyses shows that, with few exceptions, there is a close relation between structure and chemical composition, as is also the case in other groups (hexahedrites and octahedrites) of meteoric irons.

J. M. Davidson † gives the results of an analysis of the Kesen meteorite.

G. P. Merill and H. N. Stokes ‡ describe a new stony meteorite from Allegan, Michigan, and a new iron meteorite from Mart, Texas. The latter contains 89·68 per cent. of iron, 9·20 per cent. of nickel, 0·33 per cent. of cobalt, 0·04 per cent. of copper, 0·16 per cent. of phosphorus, and 0·02 per cent. of sulphur.

O. C. Farrington § discusses the nature of the so-called veins in the Farmington meteorite from Kansas, and considers that they are metallic filaments forming part of the original structure.

II.—*IRON ORE MINING.*

Diamond Boring.—J. J. Jordan ‖ gives a detailed account of the cost of diamond boring underground in Mexico; the total amounts to 6s. 7·2d. per foot.

The use of the diamond drill in exploration work is described by E. E. Lungwitz.¶

Shaft-Sinking.—A paper has been written describing the sinking by the freezing method of shaft No. 1 of the D'Auboué iron mine.**

* *Sitzungsberichte der k. preussischen Akademie der Wissenschaften*, Berlin, 1900, pp. 1122–1135.

† *Proceedings of the Rochester Academy of Science*, 1900, vol. iii. pp. 201–202.

‡ *Proceedings of the Washington Academy of Sciences*, vol. ii. pp. 41–68.

§ *American Journal of Science*, vol. xi. pp. 60 62.

‖ Paper read before the Institution of Mining and Metallurgy, April 1901.

¶ *Mining Journal*, vol. lxxi. pp. 103, 153, 178.

** *Annales des Mines*, vol. xviii. pp. 379–484, with illustrations and maps.

The first part is by C. Cavallier, and treats of the development of the ore bodies. The company's property lies in the Meurthe-et-Moselle iron ore district.

The second part of the paper is by Daubiné. The first chapter describes the preliminary studies of the property. These consisted of (*a*) an exact survey of the boundaries and the preparation of a map to a scale of 1 to 2000, showing topography of the surface, with contour intervals of 6 ft. 6 in.; (*b*) study of the deposits, as follows: 1. Thickness of the beds; 2. their composition; 3. their depth from the surface; 4. tracing of the faults, &c. Numerous borings were made, diagrams of some of them being given. These borings were from 400 to 500 ft. deep through limestone and marl, and each boring required several months to complete, at a cost of 2s. 6d. per foot. The second chapter describes minutely the putting into execution of the development project. In order to supply sufficient ore for the 600-ton blast-furnace plant to be erected in conjunction with the opening of the mine, an output of 1700 tons of ore per twenty-four hours was required. It was decided to raise this through one shaft.

The freezing process was decided to be the surest, and therefore probably the cheapest, method of sinking the shaft. The depth to the ore body is 400 ft., the ore body being 12 ft. 9 in. thick, and the sump 36 ft. 1 in. deep, giving a total depth of 448 ft. 10 in. The first 34 ft., or down to water level, was excavated and lined with masonry; then 20 borings, 460 ft. deep, were driven around the shaft in a circle, 21 ft. in diameter. The finished shaft has a diameter of 16 ft. 6 in., leaving a wall of but 2 ft. 3 in. between it and the borings. It was necessary, therefore, that the borings should be nearly vertical, a matter of considerable difficulty. Some of the borings had to be abandoned on account of being too much inclined. The methods of determining the verticality of the borings are described in detail.

Two "Fixary" ammonia ice machines, with a capacity of a ton per hour, were used, the ammonia gas being subjected to a pressure of 115 to 150 lbs. and liquefied, and then passed through two coils of pipe, the first placed in a tank of cold water, and the second in a tank of calcium chloride. The ammonia gasifies, and passes to the compressor again. The two machines worked independently of one another, two 80 horse-power engines being required to run the compressors. The circulation of the calcium chloride was maintained with a Worthington pump. The liquid was forced down the borings through a tube $4\frac{3}{4}$ inches external diameter and $\frac{7}{32}$ inch thick, and returned through

a tube $1\frac{5}{8}$ inch external diameter and $\frac{3}{16}$ inch thick. Weldless steel tubes were used. The progress of the freezing was noted by means of thermometer readings, taken every three hours, of the temperature of the ingoing and outflowing liquid and of the liquid at the bottoms of the borings. The theoretical thickness of the ice walls necessary to keep out the underground waters is discussed mathematically. After 100 days of freezing, the sinking of the shaft was resumed, and it was found that the soil was frozen almost to the centre of the shaft. Compressed powder was used first, the progress being 10 to 20 inches per day. Dynamite was used later, and the progress was 30 per cent. greater. In the marls as much as 37 feet per day were sunk. Three shifts were worked per twenty-four hours in the shaft, each shift consisting of a foreman, seven miners, and seven or eight helpers. From the water level to a depth of 368 feet below, passing through water-bearing strata, the shaft was lined with cast iron rings backed up with concrete.

Owing to the proximity of the borings to the shaft, many ruptures of the cooling tubes occurred during the work. This was at first thought to be due to the use of dynamite, but was finally found to be due to excessive stresses produced by contraction, and the subsequent lessening of the resistance produced by the cold. The sinking of the shaft 416 feet through the frozen soil and rock began July 6, 1899, and was finished July 5, 1900, a total of 364 days. From this should be deducted 53 days lost from influx of water, 47 days consumed in placing the cast iron lining, and 48 days used in building the masonry lining in the bottom section of the shaft; leaving 216 days actually devoted to the sinking, an average of 23 inches per twenty-four hours.

The last chapter gives a general description of the machinery and surface arrangements. Two double-deck hoisting cages are used, each weighing 3·8 tons, and with a carrying capacity of 6 tons of ore. These are lifted by two simple hoisting drums with flat cables. Two tandem compound condensing steam pumping-engines are placed below ground.

Air-Compressing Plant.—An illustrated description of the air-compressing plant of the Velardena Mining Company has been published.* It is the first central air-power plant to be set up in Mexico, and it is the largest single instalment of the kind in the Republic. The air-compressing plant consists of two Ingersoll-

* "Modern Mexico," vol. x. p. 29.

Sergeant duplex Corliss air-compressors, each having two cross-compound steam cylinders, 16 and 30 inch diameter by 48 inch stroke, and two cross-compound air cylinders, 15¼ and 24¼ inches diameter by 48 inch stroke. The intake air is compressed in the first or low-pressure cylinder to about 35 lbs. pressure per square inch. From there it is conducted to a large vertical intercooler, where the hot air is cooled down to atmospheric temperature, and is then led into the second or high-pressure cylinder, where it is compressed to about 100 lbs. per square inch. Thence it passes into a large vertical steel air receiver placed outside the building, where it again cools and dries before passing into the distributing main. A steam receiver is also provided between the high and low-pressure steam cylinders. The air cylinders are of the piston inlet type. Each compressor is also provided with an independent jet condenser for condensing the steam from the exhaust of the low-pressure cylinders. The capacity of the two compressors when running at rated speed of 75 revolutions, is 3666 cubic feet of free air per minute, or sufficient to run about 50 air drills; but, as a matter of fact, the Velardena Company are not using more than about 20 drills, the rest of the air being applied to running pumps, hoists, &c. The two engines are of 624 indicated horse-power.

Electric Plant.—The electric power plant of the Hollertszug iron ore mine, Herdorf-on-the-Sieg, Germany, is described,* with the aid of a number of illustrations. Two compound engines, each capable of developing 180 horse-power, drive three shunt-wound, direct-current generators by belting. These generate 45 kilowatts at 250 volts for winding, 45 kilowatts at 450 volts for pumping, compressing air, and ventilating, and 36 kilowatts at 240 volts for the electric locomotive.

R. Classen † publishes an exhaustive description of a new electric rock-drill which is in operation at Hartmanshof. The description is illustrated by means of six excellent photographs. It is found that to bore a hole one metre deep the time occupied is—

	Minutes.
Fine-grained granite	12 to 20
Very hard quartzite	10 ,, 15
Hard travertine	6 ,, 10
Very hard limestone	12 ,, 15
Carboniferous sandstone	10 ,, 20
Fine-grained red sandstone	10 ,, 12
Dolomite	8 ,, 10
Marble	5 ,, 15

The drill is of the rotary type with a diamond boring crown.

* *Iron and Coal Trades Review*, vol. lxii. pp. 387-389.

† *Glückauf*, vol. xxxvi. pp. 989-996.

Iron Ore Mining in Cleveland.—Some general notes on the Cleveland district have appeared, collected from different sources, of various, mostly ancient, dates. Included are illustrations of the surface works, and the shaft and the tubbing at Lumpsey mine.*

Iron Ore Mining in Sweden.—The methods of working in vogue in the Swedish iron ore mines are described in detail by W. Petersson.†

Mining in the Lake Superior District.—C. Brackenbury‡ gives an account of some of the methods of mining in the Mesabi range. *Inter alia* reference is made to the timber slides at the Fayal mines, and the counterbalanced cage at the Genoa mine for lowering the timber, and to the steam-heated underground rooms at several mines for thawing dynamite.

A plan and some photographs of the Biwabik iron ore mine on the Mesabi Range have appeared.§ All the ore is obtained in open workings by three steam shovels, two of which are of 85 ton and one of 65 ton capacity. An area has been stripped of more than 1800 feet in length, nearly 800 feet in width at the widest part, and ranging from 50 to 100 feet in depth. Some three million cubic yards of cover have been removed, and more ore has been uncovered than was expected. The stripping is done with the aid of five large steam shovels, seventeen small locomotives, and tipping trucks holding 2½ cubic yards each, the spoil being removed to waste heaps on the adjacent land. The open cut has been carried right through the mine, so that the ore trains can circulate continuously, and during the season of last year the shovels took out 915,000 tons of ore. Seven-ninths of this ore contained 63·75 of iron and 0·040 of phosphorus. Half the remainder contained 0·005 per cent. more phosphorus, and the other half 0·010 per cent. more with the same amount of iron. Some poorer ore was also shipped, but much of the lower grade containing 50 to 55 per cent. of iron is being piled apart, so as to obtain access to the richer beds.

On the Gogebic Range‖ most of the shafts are sunk on the ore bodies. At the Norrie mine a large shaft with four compartments is

* *Iron and Coal Trades Review*, vol. lxii. pp. 820–822.

† *Jernkontorets Annaler*, vol. lv. pp. 545–604.

‡ *Daily Mining Gazette*, Houghton, Michigan, through *Mines and Minerals*, vol. xxi. pp. 150–152.

§ *Iron Age*, December 13, 1900, pp. 4–6.

‖ *Ibid.*, February 7, 1901, p. 22.

being sunk on the foot wall, and steel beams are being used instead of timber for the support.

Some half-tone engravings and other illustrations of the mining operations in the iron ore district of Lake Superior have appeared in an account by W. Fawcett.*

A. Bachellery † gives a detailed description of the iron ore mines of Minnesota. G. Wallin ‡ also describes the iron ore mines of the Lake Superior district.

Handling Ore.—W. Fawcett § gives a picturesque account of the wharves, vessels, and appliances for handling the ore on the great lakes, and his article is illustrated by a number of half-tone plates and other drawings by E. L. Blumenschein.

W. Fawcett,‖ in another article, compares the costs of handling and transporting ore on the great lakes.

A. C. Johnston ¶ describes the shipping, charging, and discharging arrangements for iron ore and coal on the great lakes. Numerous illustrations are given of the newest forms of appliances for the above purposes that are in use.

Illustrations have appeared ** of the ore dock built of wood at West Superior, Wisconsin. It was built between January 1st and May 1st, 1900, and will hold 40,000 tons of ore. The dock is 1500 feet in length, 63½ feet broad, and 73 feet high from water to rail level. On each side there is a row of ore pockets each holding 160 tons of ore. Each pocket has a hinged shoot for loading direct into the vessels berthed alongside, and the pockets themselves are loaded from the railway waggons which run over them.

An illustration has appeared †† of a small vertical boiler mounted on a tram trolley for use in quarries and mines.

* *Century Magazine*, vol. lxi. pp. 712-725.
† *Annales des Mines*, vol. xviii. pp. 154-213.
‡ *Teknisk Tidskrift*, vol. xxxi. pp. 65-75.
§ *Century Magazine*, vol. lxi. pp. 851-863.
‖ *Iron Age*, March 21, 1901, pp. 11-12.
¶ *Stahl und Eisen*, vol. xxi. pp. 14-21; sixteen illustrations.
** *Engineering News*, vol. xliv. p. 424, with plate.
†† *Iron and Coal Trades Review*, vol. lxi. p. 1101.

III.—*MECHANICAL PREPARATION.*

Magnetic Concentration.—A description has been published* of the Wetherill magnetic concentration plant at the Lohmannsfeld Mine, in Siegerland. The ore consists of galena, zinc blende, and spathic iron ore, the last named containing 12 per cent. of manganese. The gangue is quartz. By the ordinary method of concentration only the galena could be separated. With the Wetherill separator, however, a blende with 42 to 46 per cent. was obtained, whilst the spathic iron ore contained only 1 to 3 per cent. of zinc. Three Wetherill machines have now been installed. The tension is 65 volts, and the magnets work with a current of 5 to 8 and 12 to 16 amperes. With eight men 3 to 3½ tons of ore are treated hourly at a cost of 1s. 5d. per ton.

Two papers on the concentration of iron ores were read at a recent meeting of the Swedish Society of Engineers. In the first, K. Huldt described the concentration of red hæmatite at Naeverhaugen in Norway. The ore, containing 40 to 60 per cent. of iron, is comminuted in a Gröndal mill and sorted in trommels after the preliminary breaking has been effected in a Gates stone-breaker. In the second paper G. Gröndal describes the magnetic concentration of iron ore at Pitkäranta in Finland.†

K. Winge gives the results of a microscopic examination of some of the poorer iron ores of Sweden, with a view to ascertain their suitability for concentration processes.‡

The present condition of the concentration of iron ore is described by F. G. Stridsberg.§ He describes the briquetting of iron ores in Finland. These average 22 to 32 per cent. of iron, and consist of very hard, tough serpentine, containing magnetite and sulphides. Three tons of this makes a ton of ore slimes, containing 61 per cent. of iron. The briquetting machine was made at Dorsten in Westphalia, and cost £500. The ore is passed through three Blake crushers, and then passes to eight Gröndal ball mills, working continuously, the fine ore being charged in at one point, and discharged with the wash water at another. From this crushing plant the slimes go to eight Gröndal magnetic separators, and from these the concentrates pass to the briquetting machines. The blast-furnace is about 52 feet high

* *Glückauf*, vol. xxxvi. p. 1039.
† *Teknisk Tidskrift*, vol. xxxi. pp. 39, 53. ‡ *Ibid.*, vol. xxxi. pp. 59–63.
§ *Jernkontorets Annaler*, vol. lvi. pp. 1–27.

and 9 feet 10 inches in diameter at the boshes. After leaving the briquetting presses the ore briquettes are extremely friable. They are then burnt, and afterwards become so hard that they can be allowed to fall for several yards without breaking, and when they do break they only form three or four pieces. No binding agent is employed, the right proportion of coarse and fine ore being all that is necessary. A special form of furnace is used for burning these briquettes. It is capable of burning up to 70 tons a day. The ore slimes contain 0·524 per cent. of sulphur, and as the pig iron made only contains 0·035 per cent., a large proportion of the sulphur was evidently eliminated by the briquetting process. The slime from the separators contained 11 to 12 per cent. of iron, 2 to 3 being magnetite, and the rest silicate.

E. Langguth * considers that the currents used in the electro-magnetic separation of ore must have as low an intensity and as great a density as possible, that is to say, intense magnetic fields. The ore must be passed before the separating poles steadily and at as little distance as possible, and the rate of speed at which this is done must depend on the magnetisability of the ore particles. Finally, the separation must be effected in homogeneous magnetic fields.

It is stated that experiments are being made with magnetic separators for the fine ore screened out from the run of the mine taken from the "Old Bed" at Port Henry, New York. The fines are to be crushed and concentrated to raise the iron contents. The tailings are to be treated to obtain a product rich in phosphorus. It is expected to bring the ore within the Bessemer limits.†

Briquetting Fine Ore.—H. S. Mould ‡ refers to the advantages which might accrue from drying and briquetting the fine ore from the Mesabi district, and shows that some advance has been made in the use of presses for the production of briquettes made from fine ore, magnetic concentrates, and flue dust. The earlier forms of the presses designed by B. C. White for these uses somewhat resembled mortar pan mills for mixing the ore, and the binding agent consisted of lime slurry. A horizontal disc with two rows of holes worked through the side of the pan, and the holes were filled with the mixture, which was subsequently compressed by plungers and ejected on to a travel-

* *Zeitschrift für Elektrochemie*, vol. vi. p. 500; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. p. 683.

† *Iron Age*, December 6, 1900, p. 33.

‡ *American Manufacturer*, vol. lxviii. pp. 65–73.

ling belt. In the latest form a horizontal reciprocating multiple plung press is employed. The plungers work through a feed-box into t moulds, and the feed-box is also movable, to give an independent moti under the hopper. Machines may be built to turn out 150 briquet per minute, each 3½ inches in diameter and 2¼ to 2½ inches in thi ness, weighing 2¼ to 3 lbs. each. Two mixers for lime and water worked alternately, and there is an automatic feed for the ore i the main mixer. Numerous illustrations are given, and elsewhere illustrated account of one of the pan types of press is also given.*

IV.—*METALLURGICAL PREPARATION.*

Calcining Hungarian Ores.—A. Edvi-Illés † gives the followi comparative analyses of the Rudóbánya limonite ore in its calcin and raw states:—

	Raw Ore.	Calcined Ore.
	Per Cent.	Per Cent.
Ferric oxide	68·57	70·03
Silica	10·10	10·72
Alumina	2·24	2·25
Manganous oxide	4·03	3·91
Lime	1·40	1·15
Magnesia	1·02	0·73
Cuprous oxide	0·11	0·09
Phosphoric acid	0·09	0·07
Barium sulphate	3·44	4·01
Iron	48·06	49·43
Manganese	2·91	2·82

At a number of other mines the ore is first submitted to calcinati before being charged into the blast-furnace, spathic ore being f quently mined. This occurs, for instance, at the Dobsina, Bin Zakárfalva, and other mines. Both shaft kilns and reverberato furnaces are used for the calcination. The calcined spathic ore fr Klippberg contains 62·17 per cent. of iron and 11·61 of magnesia, a that of Zahura 49·93 of iron and 8·5 of magnesia. The other c stituents are also given.

* *Iron Age*, December 20, 1900, pp. 7-8.
† *L'Industrie des Mines de Fer et Hauts Fourneaux de Hongrie:* Budapest, 19 p. 53, &c.

REFRACTORY MATERIALS.

Firebrick.—G. D. Rice * describes the manufacture of firebricks in the Philippines, where large deposits of fireclay occur. The clay is seasoned, ground, and moulded in wooden moulds, but the appliances used are, as a rule, extremely crude.

Some Iowa Dolomites.—N. Knight † gives the following results of analyses of dolomite from Iowa :—

	$CaCO_3$	$MgCO_3$	Fe_2O_3 and Al_2O_3	SiO_2
I.	78·75	20·16	0·10	0·4
II.	58·2	39·5	0·9	1·2
III.	56·4	42·6	0·7	0·4
IV.	54·02	44·73	0·61	0·3
V.	53·64	43·89	0·52	1·9
VI.	55·3	43·0	1·4	0·6
VII.	55·76	43·85	0·26	0·1

I. Rochester. II. Bieler's Quarry, Cedar County, Iowa. III. Bieler's Quarry. IV. Mount Vernon. V. Palisades, Cedar River. VI. Lime City Quarries. VII. Rock Creek.

Magnesite.—The true magnesite which is met with on the island of Eubœa is the purest that has yet been found. It contains up to 99 per cent. of magnesium carbonate. According to E. Schmatolla,‡ there are now two companies on this island that raise and export this substance, one Greek and the other English. The matrix of the magnesite is serpentine, which occurs as hill ranges on the island. The Greek company exports the magnesite from the small port of Katunia, both in its raw and calcined forms. Up to quite recently only very primitive forms of kilns were in use, and these were heated with wood. Much wood was required, and although a

* *American Manufacturer*, vol. lxviii. pp. 74-76.
† *American Journal of Science*, vol. xi. p. 244.
‡ *Stahl und Eisen*, vol. xx. 1065-1066; two illustrations.

satisfactory lignite occurs on the island, it was not utilised. It is a true lignite, showing all the structure of wood. The author has recently erected a modern form of shaft-calciner, illustrations of which are given. This uses the lignite above referred to, and is continuous in its action. Magnesite has the property of falling into powder at the least movement when once it has been fully calcined. The consequence is that this change begins to take place quite high up, and the cooling portion of the shaft becomes quite thickly packed with the powder. This will allow no gas or air to penetrate it, and a modified form of calciner, such as that illustrated, is therefore necessary. This kiln requires about 16 to 20 per cent. of lignite for the complete calcination of the magnesite.

If the magnesite is in small pieces it is best calcined in a reverberatory furnace having two hearths one above the other, and over which the flame passes directly in contact with the magnesite, this being charged in on the upper hearth, and the calcination completed on the lower one. The pure Eubœa magnesite has high fire-resisting properties, and only sinters at very high temperatures. To make magnesia bricks from the material a suitable binding material is necessary. The Greek company makes such bricks at its works at Mantudi, and uses serpentine as the binding material. The bricks produced are extremely hard and dense, and are exported for metallurgical purposes to the United States and elsewhere. The brick is burnt at about the temperature of the melting-point of steel—say 1400° C. The best ovens for this furnace are those on the Siemens regenerative principle.

The large deposits of magnesite that have been discovered in the Ufa government in the Southern Ural are stated to be of excellent quality and to contain—

MgO.	CaO.	$Fe_2O_3 + Al_2O_3$.	SiO_2.	CO_2.
46·0	0·85	1·62	0·3	51·23

This magnesite is to be utilised for magnesite brick manufacture, the erection of works near Zlatooust having been begun in September 1900.*

Graphite.—J. F. Kemp,† in discussing the pre-Cambrian sediments in the Adirondacks, refers to the deposits of graphite which occur in

* Communicated by Mr. Sergius Kern (St. Petersburg).

† *Proceedings of the American Association for the Advancement of Science*, vol. xlix. pp. 179-182.

that region. The larger deposits are limited to limestones and gneisses and the origin of the graphite is discussed.

F. Grünling * describes the occurrence of graphite in Ceylon.

H. A. Miers † summarises the scientific results derived from a trip by Grünling to Ceylon. Grünling, he shows, makes it clear that the graphite always occurs in typical symmetrical veins, though these have been much crushed and altered by earth movements which have spent their energy upon the soft graphite, and have consequently spared the country rock (granulite). Weinschenk comes to the conclusion that the graphite is of volcanic, and certainly not of organic origin, and is probably due to the action of vapours containing carbon; he suggests that carbon dioxide and cyanogen compounds have played the chief part in its production. Among the associated minerals it is remarkable that, as at Passau, nontronite is one of the invariable decomposition products accompanying the graphite.

T. C. Hopkins ‡ states that graphite is now mined at three places in Pennsylvania, and there are besides several abandoned mines. At Chester Springs there are two veins or layers of disintegrated mica schist containing graphite. One is 4 feet and the other 6 feet in width, and the output is about 2 tons daily. At Byre station a cruder material is produced. Near Mertztown, in Northern Berks county, about 2 tons daily is produced from a lenticular deposit in a coarse grained sandstone.

* *Zeitschrift für Krystallographie*, vol. xxxiii. pp. 209–239.
† *Nature*, vol. lxiii. pp. 453-454.
‡ *Mines and Minerals*, vol. xxi. p. 352.

FUEL.

CONTENTS.

I.—*CALORIFIC VALUE.*

Calorimetry.—Parr* describes a form of calorimeter in which the powdered fuel is burnt with sodium peroxide. An allowance has to be made for the heat of combination of the products of combustion with the caustic oxide.

Pyrometry.—H. L. Callendar† discusses the measurement of extreme temperatures, chiefly in connection with the attempts made to measure the heat of the electric arc and of the sun, which depend on extrapolation in formulæ founded on the melting-points of various bodies. The author has applied the method of the Wheatstone bridge to transpiration thermometry with some hopes of success. In this system the rate of flow of gases through fine tubes, which depends on the viscosity and the expansion of the gas, is observed, and the rate of flow is measured by balancing it against flows under similar resistances in other tubes, exactly on the principle of the electric bridge method.

An effort is being made in America to form a national standardising bureau, and evidence is being taken on the questions involved. Special reference was made to the calibration of pyrometers for use in

* *Journal of the American Chemical Society*, vol. xxii. p. 646.
† *Proceedings of the Royal Institution of Great Britain*, vol. xvi. pp. 97–118.

the manufacture and further treatment of steel. The use of the pyrometer in determining the proper temperature to which a jacket should be heated for shrinking it on to a gun tube is given as an example.*

Some illustrations are given † of several forms of German pyrometers. In one form platinum and an alloy of nickel and platinum are used to form the thermo-couple.

D. S. Jacobus ‡ describes a Le Chatelier pyrometer, in which any error due to variations in the resistance of the platinum and platinum-rhodium element is eliminated. The electromotive force generated by the element is balanced by counter-electromotive force produced by a number of secondary elements surrounded by steam and by melting ice. When the element has to project a considerable distance into the heated space, the leads are protected by a water-jacket.

An air pyrometer § has been introduced, with which it is possible to measure temperatures up to 2000° F. The instrument describes a continuous curve on a revolving graduated disc, and is not affected by the fluctuations of the atmospheric pressure.

W. H. Bristol ‖ describes a recording pyrometer with a porcelain air-bulb connected by a capillary tube to a Bourdon pressure gauge which has an automatic recording attachment. The bulb is partly exhausted of air so as to diminish the risk of distortion of the tube as the pressure rises, and the pointer is connected to a second Bourdon tube wound in the opposite direction to the first, so that alterations in the external temperature and pressure automatically compensate themselves. The instrument has been calibrated up to 2000° F.

II.—*COAL.*

The Composition of Coal.—C. A. Seyler ¶ continues his paper on the chemical classification of coal, and is of the opinion that hydrogen seems to be more important than carbon in determining the kind of

* *Iron Age*, January 3, 1901, pp. 30-31.

† *Iron and Coal Trades Review*, vol. lxii. p. 442.

‡ *Proceedings of the American Association for the Advancement of Science*, vol. xlix. p. 151.

§ *Engineering*, vol. lxxi. pp. 150-151, nine illustrations.

‖ American Society of Mechanical Engineers, New York Meeting, through the *Engineering News*, vol. xliv. p. 411.

¶ *Proceedings of the South Wales Institute of Engineers*, vol. xxii. pp. 102-120 see *Journal of the Iron and Steel Institute*, 1900, No. II. p. 429.

coal. A scheme for the classification is now given, in which the percentages of carbon and hydrogen form the co-ordinates. The carbon limits are over 93·3, 93·3 to 91·2, 91·2 to 89·0, 89·0 to 87·0, 87·0 to 84·0, 84·0 to 80·0, and 80·0 to 75·0. The hydrogen and volatile matters form the other co-ordinate in the table, and are as follows:—

Hydrogen . .	over 5·8	5·0 to 5·8	4·5 to 5·0	4·0 to 4·5	under 4
Volatile matter .	over 30	23 to 30	16 to 23	10 to 16	under 10

The discussion on the first part of the paper turns on the calorific value and other matter.

T. Baker * gives the results of some experiments on the solvent action of pyridine on certain coals. Some guide as to the coking properties may be obtained by experiments in this direction.

The Formation of Coal.—C. Ochsenius † controverts the conclusions arrived at by Gosselet,‡ who appealed to the evidence of level as destructive of the hypothesis of the origin of saline waters in Carboniferous strata by infiltration from ancient or modern seas.

B. Renault, § discussing the peaty marshes of Palæozoic times, shows that the fermentation of plant remains at that remote epoch did not necessarily result in the formation of coal.

Compressive Strength of Coal.—W. Griffith ‖ has made some rough tests to determine the load that coal will sustain before crushing. An average of eleven tests gives 4·67 tons per cubic inch. H. Louis has elsewhere given the yield point at about 200 tons per cubic foot, and states that complete crushing takes place at 400 tons. The Scranton Engineers' Club has issued a circular asking for co-operation in a complete series of tests.

The Kent Coalfield.—In the course of evidence before the King's Bench, Brady ¶ states that he started the first bore-hole (9-inch) for coal in June 1886. In February 1890 the first seam of coal was struck. The boring was subsequently continued until July 1893. The number of coal seams met with was ten. Of these, three were

* *Transactions of the Institution of Mining Engineers*, vol. xx. pp. 159-163.
† *Zeitschrift für praktische Geologie*, vol. ix. pp. 19-20.
‡ Paper read before the International Geological Congress, Paris, 1900.
§ *Bulletin du Muséum d'Histoire Naturelle*, 1900, pp. 44, 48, 202.
‖ *Mines and Minerals*, vol. xx. p. 451; vol. xxi. p. 19.
¶ *The Times*, February 20, 1901.

under 2 feet thick, and the rest of greater thickness. No steam-coal had been found; it was all house or gas coal. There were indications that more coal existed below the deepest point reached in the bore-hole. The lowest seam struck was found at a depth of 2200 feet. The seam struck at a depth of 1763 feet was 2 feet 9 inches in thickness, and was as good as Welsh coal. Three shafts were in progress, one being 937 feet deep. At a depth of 590 feet a seam of workable iron ore was found 15 feet in thickness.

Coal in Shropshire.—W. Shone * discusses the unconformity of the Upper Red coal measures to the Middle Grey coal measures of the Shropshire coalfields, and its bearing upon the extension of the latter under the Triassic rocks. The Upper Red measures have a much greater extension in the Shropshire coalfields than the productive measures below. In the Shrewsbury field they are the only Carboniferous rocks present, and they rest on pre-Carboniferous rocks.

Coal in Staffordshire.—W. Gibson † discusses the upper coal measures surrounding the margins of the North Staffordshire coal-field and their bearing on the extension of the coalfield to the west.

The position of the Permo-Carboniferous boundary as affecting the knowledge gained from the Sealand and Thurgarton bore-holes is discussed by W. J. Clarke.‡

Coal in Yorkshire.—H. T. Foster § gives some notes on the geology of the Thorncliffe district in South Yorkshire, with many sections of the seams and adjacent strata.

T. Ashley ‖ gives a detailed account with plans and sections of the Adwalton stone coal and the Halifax hard bed coal, and deals with their origin.

L. B. Wells ¶ gives a section of the strata above the Barnsley coal passed through in the bore-hole at South Carr in Lincolnshire.

Coal in Scotland.—R. W. Dron ** gives some notes on the geological formation of the Carboniferous limestone series, with especial

* *Quarterly Journal of the Geological Society*, vol. lvii. pp. 86–95.

† *Transactions of the Institution of Mining Engineers*, vol. xx. pp. 73, 78, 111, 115.

‡ Paper read before the Chester Society of Natural Science, March 28, 1901.

§ *Journal of the British Society of Mining Students*, vol. xxiii. pp. 68–77.

‖ Paper read before the Yorkshire Geological and Polytechnic Society, November 1900; *Iron and Coal Trades Review*, vol. lxi. p. 994.

¶ *Transactions of the Manchester Geological Society*, vol. xxvii. pp. 57–64.

** Paper read before the Geological Society of Glasgow, January 1901.

attention to the fact that about a quarter of the coal still to be worked in Scotland lies in the concealed portions of these strata. The various districts are considered.

Coal in Ireland.—A recent report of the Cork Chamber of Commerce includes some remarks on the future of the Irish coal industry, with especial reference to the railway facilities; but it is considered that the outlook is not promising in view of the depth of the collieries and the position of the railway companies.*

Coal in Austria.—Julius Sauer † describes the Rossitz coalfield in Moravia. The main seam averaged 4 yards in thickness. The deepest shaft in the field is the Julius pit, which is 490 yards in depth. Last year 2628 miners were employed. For the past ten years the nine-hour shift from bank to bank had been adopted. The output last year was 449,936 tons, or 171·2 tons per miner. The average annual output per miner was—

1885-91	165·5 tons (12 hours shift).
1892-99	178·9 tons (9 hours shift).

Söhle ‡ gives a geological description of the neighbourhood of Semil, Starkenbach, and Leibstadtl, in Bohemia, with special reference to the coal met with at the last-named locality.

Coal in France.—A detailed study of the Decazeville coalfield, Aveyron, has been published by Bergeron,§ Jardel, and Picandet.

A descriptive account of the Bessèges Collieries in France has been published.‖ The area of the coalfield worked by the Company extends over 7250 acres, and is divided into two distinct centres of working, which are known as the Bessèges and the Molières divisions. Recent explorations have disclosed in the former division a fresh group of workable seams, two of which are already proved. The coal yields a good blast-furnace coke when treated in the Coppée ovens, although containing only 18 per cent. of volatile matter against 28 per cent. in the old Bessèges group. The Molière division yields bituminous coal, but as at Bessèges, on proceeding southwards the volatile

* *Globe*, March 7, 1901.
† *Zeitschrift des Oesterreichischen Ingenieur- und Architekten-Vereines*, vol. lii. p. 746.
‡ *Montan Zeitung*, vol. viii. pp. 115–117.
§ *Bulletin de la Société Geologique de France*, vol. xxviii. pp. 715–748.
‖ *Colliery Guardian*, vol. lxxx. pp. 1368–1369.

matter diminishes, and it becomes necessary to enrich with bituminous coal the coal intended for coking. These two divisions have recently been connected by a cross-measure drift, over 3 miles long, at a depth of about 430 feet below sea-level. It was supposed that a series of sterile seams lay between the two main groups of workable seams, and the drift was made partly with the object of ascertaining the truth of this supposition. Driven from one side only, the work occupied much time, but it resulted, first, in revealing the presence of the new seams at Bessèges, and secondly, in approaching Molières, in the discovery of a number of non-bituminous seams of from 2 to 4 feet in thickness, eight of which will be worked to advantage. A full description of the colliery plant and winding arrangements is given.

The Roche-la-Molière et Firminy Company * has a concession which occupies the western portion of the Loire coalfield, extending $6\frac{1}{2}$ miles from north to south, with a mean width of 3 miles east and west. It contains all the seams of the lower, middle, and upper Saint-Etienne group, as defined by Gruner. In the Roche-la-Molière district the Siméon seam has been proved over an extent of 650 yards, and has a mean thickness of 19 feet, and other seams have proved to be almost equally extensive. A model of the workings in the main seam in the Malafolie district was exhibited. The samples of coal showed that almost all varieties are being worked, from semi-bituminous, with 16 per cent. volatile matter, to long flame bituminous containing 38 per cent. of gaseous constituents. The coals of La Malafolie are equal to the best gas-coal, and are much in request for house purposes. The total output in 1899 was 927,148 tons, against 907,309 tons in 1898.

Babu † gives analyses of lignites from Isère, and from Voglans in Savoy; and of coal from Saint-Éloi, Puy-de-Dôme; from Allevard, Isère; and from Langeac, Haute-Loire. Anthracite from Savoy was found to yield—

Moisture.	Volatile Matter.	Fixed Carbon.	Ash.
4·68	2·27	76·91	16·14

Coal in Germany.—Middelschulte ‡ discusses the geology of the Ruhr coalfield.

Holzapfel § shows how coal-bearing strata occur in the dips of the Variscite ranges. Between the deposits of Osnabrück and Illenbüren

* *The Colliery Guardian*, vol. lxxx. pp. 1253-1254.
† *Annales des Mines*, vol. xviii. pp. 496–497.
‡ *Glückauf*, vol. xxxvii. pp. 301-305.
§ *Naturwissenschaftliche Wochenschrift*, January 6, 1901, pp. 1-6.

and the coal-beds in the Ruhr Valley, those near Aix and the basin of Belgium and Northern France, a distinct connection is traceable, but none can be found to exist between the Ruhr district and the coal-fields of Upper Silesia. The small inland coal-basins would appear to be of local origin.

K. Baumgartner * describes some peculiar pressure effects, so-called "pillar shots," observed at the Hausham colliery in the Upper Bavarian coal-basin. The faults, too, that occur in this coal-basin are also dealt with in detail.

Coal in Hungary.—In the history of mining,† Hungary takes a prominent place among the countries of Europe. It may be considered as the classic land of mining, inasmuch as traces of a metallurgical industry dating back to a remote antiquity are found. The coal industry has, however, practically no past, though undoubtedly the mineral has been known in Hungary, as in Western Europe, for centuries. It was found here and there by those engaged in gold-mining, but it remained unused, as the vast forests supplied all the fuel needed, and it was only after the forests were devastated that the want of coal began to be felt. Towards the middle of the eighteenth century a smith, who had become familiar with the use of coal abroad, discovered the beds of coal at the Brennberg, and from that time the deposits have been worked; but it was not until the inauguration of steam navigation on the Danube that the industry was developed on a large scale. The discovery of other important coal-beds then followed, and, thanks to careful geological surveys, practically all likely localities for coal are now known. About fifty years ago the idea of working coal was still a novelty. A few brown coal deposits were worked, as well as some of the Liassic coal-beds, to supply the steamers plying on the Danube. Little was written in English on the progress of the industry until 1886, when Bennett H. Brough read a paper on the subject before the Society of Arts. The Exhibition at Budapest in 1896 led to further publications on the mining industries of the country, but it was not until 1900, at the Paris Exhibition, that the kingdom of Hungary was adequately represented among the countries that displayed their mining and metallurgical products. The annual output of coal and brown coal now exceeds 5¾ million tons.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. pp. 461-466, 476-482, 489-493, with two sheets of illustrations.

† *Colliery Guardian*, vol. lxxxi. p. 71.

The consumption of brown coal has increased much more rapidly than that of coal, owing to the fact that the deposits of the former are so much more extensive than the coal seams. The production of coal has not hitherto kept pace with the increasing demand, consequently the extraction of coal in that country has a promising future.

An extensive coalfield has been discovered in the Banat mountains, in Southern Hungary. The coal is of Liassic age and anthracitic in character.*

Coal in Roumania.—Coal is of frequent occurrence in Roumania. According to P. Poni,† anthracite containing 88 to 90 per cent. of fixed carbon is worked at Schela in the Gorjin district. Jurassic coal occurs in the Dimbovitza district, whilst lignite is being mined at a number of localities.

Coal in Russia.—E. Ladoff‡ describes the recently discovered coal seams at Tkwartschali in the Caucasus. They are in the province of Kutais, some thirty-five miles from the sea coast. It is a very mountainous district, through which run several rivers in deep-cut beds. The chief of these is the Galisga, into which flow a large number of tributaries. There are numerous waterfalls, and the country is thickly wooded. The first seam noticed was about 2·5 feet in thickness, and two others, one 7 feet and one of 14 feet thick, have since been found. The new coal district has an area of about eighty square miles, but it has so far been very little investigated. The coal is found in sandstones, high in alumina contents. These occasionally pass into schist, and are covered by conglomerate. Faults are of common occurrence. Owing to the deeply-cut river gorges, the seams of coal are found to outcrop in many places. The author mentions three seams of the thicknesses already given. These are on the Araschra and Mokaguara. The ash contents is very variable. The coal is of good quality and cokes well, even coal containing as much as 33 per cent. of ash yielding a readily coherent coke. In order to open up these deposits a line of railway to the harbour of Otschemtschiri is necessary. It would not be an easy matter to build this railway, however, and perhaps an electric line or a wire ropeway would be the better way to open up these deposits, to the future of which the author looks hope-

* *Montan Zeitung*, vol. vii. p. 558.
† *Annales Scientifiques de l'Université de Jassy*, 1900, pp. 15-148.
‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlix. pp. 173-174.

fully forward. The coal seams occur at an elevation of about 1550 feet above sea level.

F. F. Kleye * gives further details as to the coal deposits on the Island of Saghalien (Sachalin). Mention of these coal deposits was made in the last century. Thus the French navigator Laperouse mentions that in July 1787 he observed rounded pieces of coal on anchoring in an unimportant bay on the southern side of the western shores of the island. The first attempts to work these deposits were made in the fifties. A Russian expedition in the year 1852 found two coal seams, 6 feet thick, near Cape Jonquière, while a few miles away several other coal seams were found from 2 to 3 feet in thickness. In this and the next following years a few tons of this coal was mined by the sailors forming a portion of the expedition for their own use. From September 1, 1862, chain-gangs of prisoners were exclusively used in working these deposits. Each prisoner was paid a certain sum in money at once for every pood of coal he mined. The system of mining adopted was at first little more than robbing, but the annual consumption of the coal at that time did not exceed 200,000 poods. Soon about 800,000 poods of coal had accumulated in stock, and in 1864 all coal-mining was temporarily stopped. It was not resumed until the second half of 1867. In 1869, 800 prisoners were sent to the island. The wages paid to them were stopped, and the mines worked systematically by this forced unpaid labour. In 1871 a mining engineer named Kepper was ordered to the island, and from 1871 to 1873 he made a series of careful investigations in the neighbourhood of Port Due. The coal seams he examined extended for two versts along the shore and for some 250 fathoms inland. The coal contents amounted to about 111 million poods, of which some 71 million poods could be mined. It may, however, be safely concluded that the coal measures extend farther into the interior of the island. The coal was found not to be so good as the best Cardiff coal, but it was considerably better than the best Japanese coal, which was mined at that time on the Island of Yesso. Other coal seams were soon afterwards found cropping out at other points on the west coast of Saghalien. Especial notice is made of those found between the mouths of the rivers Sertunia and Noijassi and at the mouth of the river Mgatsch in the Tartar Straits. The coal output of the Crown workings was not more than from 2000 to 4000 tons a year in the period 1860–73. Private capital was subsequently utilised for coal-mining in the island, while

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. pp. 573–577.

the Crown workings were also increased, especially since in 1872 it was found that the coal mined was inadequate in quantity for the use of the Russian fleet, which had to purchase Japanese coal. At this date the coal-mining industry of Japan was undergoing rapid development, though the best coal was only obtained from two seams on the Island of Takasima, at no great distance from Nagasaki. The subsequent progress of coal-mining in Saghalien is traced by the author both historically and statistically. The following is an analysis of coal from Due :—

Carbon.	Hydrogen.	Oxygen and Nitrogen.	Sulphur.
83·39	5·60	7·57	0·17

In addition the coal contained 1·71 per cent. of moisture and 1·56 per cent. of ash. The coke amounted to 65·0 per cent., and the coal yielded 8249 calories. The Mgatsch coal contains, in one instance quoted, 87·93 of combustible constituents, 10·2 of ash, and 1·87 of water. Comparative practical tests were made of the Saghalien coals as compared with Cardiff coal, which showed results greatly in favour of the latter. A mixture of Due and Mgatsch coal is stated, however, to be only about 10 per cent. worse than Cardiff coal, as regards consumption, from the point of view of steamship use. Apart from the coal consumed on the island and that used by steamers in filling up their bunkers, the exports have been as follows :—

Year.	Due Coal.	Mgatschi and Sertunai Coal.
	Poods.	Poods.
1893	382,168	338,830
1896	546,034	453,096
1897	781,014	663,772
1898	1,077,335	627,874
1899	1,500,000	800,000

Some short notes * on the coal deposits of Siberia direct especial attention to the deposits of Vladivostock, the island of Saghalien, and the Kuznetsk basin in the Tomsk district.

M. Stirrup † in the course of a description of the Great Siberian Railway, remarks that explorations were being made all along the line of the railway with a view of providing fuel for the use of the engines. Coal had been found in many places. Some of the beds

* *Iron and Coal Trades Review*, vol. lxi. pp. 1107–1108.

† *Transactions of the Manchester Geological Society*, vol. xxvii. pp. 43–56.

were pronounced to be of Carboniferous age, and a good many of Jurassic age, whilst lignites had been found which were no doubt of Tertiary age, some of these being of great thickness.

Coal in Spain.—An interesting coalfield is that of San Juan de las Abadesas, in the Eastern Pyrenees. It lies due north of Barcelona, with which it is connected by 70 miles of railway. According to F. Hupfeld,* on Silurian slates and Devonian limestones, Carboniferous strata are deposited, consisting of quartzite and coal embedded in shales and sandstones. The coal is not of uniform character. It is very brittle, and the various classes are mixed and made into briquettes. The cost of working is high, and the amount of coal available is not very great.

Coal in Canada.—H. M. Ami † discusses the subdivisions of the Carboniferous system in Eastern Canada, with special reference to the position of the Union and Riversdale formations of Nova Scotia, which are referred to the Devonian system by some Canadian geologists.

E. Gilpin, jun.,‡ gives a number of analyses of Canadian coal shown at the Paris Exhibition.

Coal in Queensland.—A Report on the Permo-Carboniferous coal measures of Clermont, by B. Dunstan, has been published by the Geological Survey of Queensland. In the district described there are several tracts of coal measures, the largest area exposed being that of Blair Athol. There are also tracts of granite, of slates and schists with auriferous quartz reefs, and of Devonian and Tertiary strata. It appears that upwards of 65,000 tons of coal have been obtained from the Blair Athol coalfield during the past ten years, and that more than seven million tons of the best Clermont coal are still available. The coal is well adapted for locomotives, and has been mainly used for them. It is remarked that in the coal measures there are strata derived from the auriferous slates and schists, and that therefore there might have been streams entering the old Carboniferous lagoon, which brought gold into channels now hidden by more recent accumulations: hence future developments may lead to the discovery of some of these gold-bearing alluvial deposits below the coal seams.

* *Zeitschrift für praktische Geologie*, vol. ix. pp. 145–146.

† *Transactions of the Nova Scotia Institute of Science*, vol. x. pp. 162–178.

‡ *Ibid.*, pp. 248–252.

Coal in New South Wales.—C. E. Bertrand* describes a specimen of kerosene shale from the Megalong Valley, near Katomba. It is a transition form between Boghead and cannel.

Coal in Victoria.—According to J. Stirling,† there are three well-defined coal-bearing areas in Victoria—the Gippsland district, the Cape Otway, and the Wonnan districts—covering an area of 7000 square miles, and two distinct classes of coal—the Jurassic black coal and the Tertiary brown coals in the Calloren deposits of enormous thickness. In the Wonnan beds several freshwater fossil fishes have been found, and the Gippsland beds contain plants analogous with those of some of the Indian deposits. The general character of the Victorian Jurassic coal is that of a good steaming and domestic fuel. Average analyses show—

Water.	Volatile Matter.	Fixed Carbon.	Ash.
4 to 10	25 to 36	54 to 61	3 to 8

Several beds from 20 to 200 feet in thickness have been found; and at Morwell a face 70 feet in depth is being worked open cast.

Coal in New Zealand.—A. McKay‡ has investigated the coal deposits of Puponga and Pakawau, in Collingwood County, New Zealand. On West Wanganui Inlet the coal outcrops with a thickness of 7½ feet. In the southern part of the district it is bituminous and semi-bituminous, becoming non-bituminous in the northern part.

Coal in Natal.—The syndicate which is working the seam of coal recently discovered at Greytown § are pushing their work forward. Analysis shows a coal which, while not of the very best, possesses the essential qualities of a profitable seam. There are two seams disclosed, and four tunnels are being driven upon them. The analytical results are as follows:—

	Top Seam.	Bottom Seam.	Coal as Bagged.
Specific gravity	1·43	1·42	1·45
Moisture	1·85	1·80	1·55
Volatile matter	18·80	14·41	13·51
Fixed carbon	69·01	69·74	73·60
Ash	10·34	14·05	11·34

* *Annales de la Société Geologique du Nord, Lille*, vol. xxix. p. 25.

† *Imperial Institute Journal*, vol. vii. p. 15; *Colliery Guardian*, vol. lxxx. p. 1074; *Iron and Coal Trades Review*, vol. lxi. pp. 1046–1047.

‡ *Colliery Guardian*, vol. lxxx. p. 988.

§ *Times of Natal; Mining Journal*, vol. lxx. p. 1594.

Coal in Rhodesia.—At the present time there are no producing collieries in Rhodesia, but some will shortly be opened in the Wankie and Tuli districts. Coal is also found on the southern bank of the Zambesi, but the transport is too difficult. In the Wankie field a seam 16 feet in thickness has been encountered at a depth of 48 feet in one place, and it shows fair to good coal. In the Tuli district there appear to be several basins, and some shafts have been put down striking several seams up to 3 feet in thickness.*

The report of the experts sent out by the British South Africa Company to inquire into the reported find of coal in Rhodesia practically confirms the original statements made in regard to it. The coalfield is situated some 180 miles north-west of Bulawayo, and is known to extend over at least 400 square miles. The seams vary from 5 to 16 feet in width, and as the coal lies within 40 feet of the surface, it will be worked by means of inclines instead of shafts. It is estimated that at least 1,500,000 tons will be available after making allowance of 20 per cent. for loss. In so large an area the quality naturally varies, but it is stated that the coal is better than that now in use in the Transvaal, Natal, and Cape Colony, and in some cases compares favourably with the best Welsh coal. In view of the confirmation of the value of the discovery it has been decided to take the Cape to Cairo railroad through the centre of the coalfields and on to Victoria Falls. The survey of this line is almost completed, and the commencement of the work of construction has only awaited the confirmation of the value and extent of the coal deposits.†

Coal in Trinidad.—It is stated that considerable deposits of coal exist in the island of Trinidad, and that they are of excellent quality. In the Piparo Valley three seams 2, 4, and 6 feet in thickness have been found within a depth of 40 feet. San Fernando, the second port in the island, is not far from the coal district.‡

Coal in the United States.—In an elaborate paper read before the Geological Society of America, C. R. Keyes § discusses the unconformity at the base of the coal measures in the United States, and the thickness and correlation of the measures in the different States.

* *Iron and Coal Trades Review*, vol. lxi. p. 936.
† *Mining Journal*, vol. lxx. p. 1480.
‡ *Vaughan's Weekly*, December 15, 1900, through the *Engineer*, vol. xci. p. 43.
§ *Engineering and Mining Journal*, vol. lxxi. p. 50.

C. Scholz * discusses the questions raised by C. Catlett † of the thickness of the seam in relation to that of its outcrop, and shows how the thickness varies, and how requisite it is to use all means of exploration to determine the value.

Coal in Alaska.—W. Packard ‡ refers to the outcrops of coal on the coast of Alaska, especially near Cape Lisburn and Cape Sabine. Many of them are large, and in one case formed a ridge 60 feet wide.

Coal in New Mexico.—A. Lakes § gives a short account of the Cerrillos Colliery in New Mexico, where there is a 4½ foot seam of bituminous coal, and 50 to 75 feet below is another seam 3½ to 4 feet in thickness of anthracite, overlain by intrusive porphyrite. The author also adds some notes on the coal-bearing country between Laguna and Cuavez Mesa.

Coal in Ohio.—C. S. Prosser ‖ reviews the classification of the Coal measures in Ohio, giving those which have been adopted by various authorities, and proposing the names of Dunkard, Monongahela, Conemaugh, and Alleghany for the alternate barren and productive upper and lower measures.

Coal in Pennsylvania.—Twenty-five years is the limit often given to the producing power of the Connellsville coke district, but this is probably too large an estimate in view of the present great increase of output.¶ A second seam exists below the 9-foot seam now worked, and it may enable the ovens to draw on a further supply. Much coke breeze has been piled in waste heaps throughout the district, and will be more extensively utilised in the future. W. G. Irwin ** notes that the coal basin in Greene County, in the south-west of Pennsylvania, has not been worked owing to lack of railway facilities, but is now being opened up. The same statements also apply to the Klondyke field in Fayette County.

Some statistics of the Pennsylvania district have appeared showing

* *Transactions of the American Institute of Mining Engineers*, Richmond Meeting, February 1901.

† *Journal of the Iron and Steel Institute*, 1900, No. II. p. 439.

‡ *New York Evening Post; Colliery Guardian*, vol. lxxx. p. 1151.

§ *Mines and Minerals*, vol. xxi. pp. 341-342, 375-376.

‖ *American Journal of Science*, vol. xi. pp. 191-199.

¶ *Engineering and Mining Journal*, vol. lxx. p. 339. ** *Ibid.*, pp. 339, 519.

that of the 54 million tons of anthracite produced,* 88·7 per cent. was shipped, 9·2 per cent. used at the mines, and 2·1 per cent. sold at the mines. There were 979 pumps at work raising 12·1 tons of water per ton of coal. At the collieries there were 140,583 workmen, producing 440 to 310 tons, or an average of 384 tons per year each.

D. White † discusses the age of the coal at Tipton, Blair County, Pennsylvania.

Coal in Rhode Island.—N. S. Shaler ‡ has prepared a report on the geology of the Narragansett basin, giving much information on the economic resources of the district. The coal-beds of the Carboniferous series are the most important, but none of them have been worked for many years. As to the best places for future exploration, it is recommended that the beds should be sought in the central parts of the synclines. The coal formerly raised at the Portsmouth mine, Rhode Island, yielded 10·47 per cent. of moisture, 5·83 per cent. of volatile constituents, 66·95 per cent. of carbon, and 17·05 per cent. of ash.

Coal in the Philippines.—Since the practical conclusion of hostilities in the Philippines a mining bureau has been established at Manila, by which mining papers are cleared and titles to lands sought out; and a great movement is now in progress towards the development of the coal-beds in the southern section of the Archipelago.§ In most cases the deposits have been discovered by miners who were prospecting for gold, silver, and other valuable deposits known to exist in the islands. Two great belts of coal have been traced, extending through the whole group, south-west and north-east; in the island of Bataan, in particular, extensive beds of good grade have been found, and are already partially developed. Since 1827 coal has been worked by the natives, but the lawlessness of the country prevented the establishment of any adequate mining equipment, and the mining was only conducted with the crudest instruments; at some native mines they did not use a single metal tool. Little hammers made by entwining sharp-pointed stones to the end of a stick were employed as picks, and barely sufficient coal was raised to supply the water-craft plying with

* *Engineering and Mining Journal*, vol. lxx. pp. 362–363.
† Paper read before the Geological Society of America.
‡ *The U.S. Geological Survey Monographs*, vol. xxxiii. pp. 7–88.
§ *Iron and Coal Trades Review*, vol. lxi. pp. 1270–1271.

freight between the islands. The coal is said to be of better quality than either the Australian or Shanghai coals, and the cost, compared with the imported kinds, is of course much lower; but owing to the bad management of the mines, none of the shipping nor the local industries have ever been able to rely on a regular supply, and the importation of coal has continued as a necessity. There is now a reasonable prospect in the near future of the full development of the natural resources of the islands.

According to G. D. Rice,* the largest deposits of coal found in the Philippines are on the islands of Cebu and Negros, while Bataan is reputed to contain coal in abundance of good quality. Not much has as yet been done on the other islands. The chief colliery is that of Uling-Uling on Cebu. Apparently the coal is of Tertiary age, and the seams are often much broken across by volcanic action. Transport is difficult, but labour is very cheap.

Coal in Mexico.—E. Ludlow † states that the coalfields of Mexico have not been developed to any great extent, except perhaps at the Fuente mines, near Eagle Pass, where lignite is worked. In the Sabinas valley some thin seams are worked, and there are 120 coke ovens. At Laredo lignite is also worked, but the anthracite in the State of Sonora is too far from transport facilities to be developed.

The geological formation overlying the coal deposits in Mexico forms the subject of an article published by R. L. Watson.‡ The coal occurs in a chalk formation, and is bituminous in character. A brief description of the different mines is given.

An account has been published § of the mines of the Mexican Coal and Coke Company at Las Esperanzas, Coahuita, Mexico. The coal was discovered in the autumn of 1898, and active work was begun on November 5, 1899. Shipments began in June 1900, and in December of that year they reached 15,000 tons. It is intended to push the development to an output of 5000 tons a day. The coal area contains about 50,000,000 tons. The coal, which is of Cretaceous age, yields on analysis 2 per cent. of moisture, 20·5 per cent. of volatile matter, 67·7 per cent. of fixed carbon, and 9·8 per cent. of ash. The coke ovens, 100 in all, of which 50 are completed, will produce 2500 tons a month. The yield is 60 per cent. of the coal coked.

* *American Gas Light Journal; Mines and Minerals*, vol. xxi. pp. 205-207.
† *Engineering and Mining Journal*, vol. lxxi. p. 331.
‡ *Mines and Minerals*, 1901, pp. 249-251; four illustrations.
§ "Modern Mexico," vol. xi. pp. 24-26.

Coal in Chili.—Details are published * of some important beds of coal in Chili, situated thirteen miles from Lautaro. Analysis shows the coal to be equal to that of Lota, Coronel, and Talcahuano.

Coal in New Caledonia.—According to F. Danvers Power † all the coalfields of New Caledonia are situated on the west side of the island, and may be divided into the Noumea, Moindou, Poya, and Voh basins. The coal is probably of the Triassic or Jurassic age. At the present time no collieries are being worked. It is remarkable that New Caledonia has not made itself independent of the Australian supply. The coal contains 1 to 6 per cent. of water, 5 to 18 per cent. of volatile constituents, 70 to 86 per cent. of carbon, and 0 to 21 per cent. of ash.

Coal in China.—F. L. Garrison ‡ describes the mining and industrial development of China in reference to the coal, iron, and other matters.

G. H. Monod § describes the deposit of Devonian anthracites at Lan-mon-tchang, in China. The observations recorded show that in China coal was formed at the Devonian and Carboniferous epochs, during a portion of the Jurassic period, and in certain Tertiary lagoons.

Coal in Japan.—A Foreign Office report on the trade of Nagasaki in 1899 contains some particulars of the Japanese import and production of coal. ‖

In connection with some discussion as to the suitability of the coals from Hokkaido, in Japan, for gas-making purposes, the following assays have been published : ¶—

Name of Mine.	Specific Gravity.	Moisture.	In 100 parts Coal dried at 100° C.				
			Ash.	Coke.	Per Cent. of Carbon as Coke.	Volatile Matter.	Sulphur.
Yubari . .	1·200	1·46	4·57	57·11	52·54	42·89	0·311
Sorachi . .	1·220	2·95	4·10	59·46	55·86	40·04	0·836
Ikushumbetsu	1·220	3·16	5·10	55·60	50·50	43·42	0·344
Poronai . .	1·240	4·36	7·74	59·99	52·25	40·01	0·411

* *Revista de Minas*, vol. i. No. 9.
† *Transactions of the Institution of Mining and Metallurgy*, vol. viii. p. 426.
‡ *Mining and Metallurgy*, New York; *Colliery Guardian*, vol. lxxxi. pp. 237–238.
§ *Comptes Rendus de l'Académie des Sciences*, February 16.
‖ *Colliery Guardian*, vol. lxxx. p. 1372.
¶ *Iron and Coal Trades Review*, vol. lxi. pp. 1056–1057.

In a paper on the industry of the Far East, Hartig * gives some particulars of the Japanese coal trade. The coal is very soft in the Miike district, where one mine produces over 2000 tons a day of coal containing 8·6 to 13 per cent. of ash. The coal yields about 60 per cent. of firm coke.

Peat.—P. R. Björling † gives an account of peat and compressed peat as fuel. In the raw state peat contains 75 to 85 per cent. of water, but this is reduced to 5 to 15 per cent. by air-drying, and then it contains 5 to 15 per cent. or more of ash. The composition may vary between

Carbon.	Hydrogen.	Oxygen.	Nitrogen.
50 to 66	4·7 to 7·4	28 to 30	1·5 to 3·0

In its air-dried state the calorific value is 3000 to 3500 units, or dried at 100° C., 5200 units. A short account is given of the various methods which have been adopted from time to time for cutting and preparing and compressing peat. Some of the attempts to manufacture peat charcoal are also dealt with, a number of illustrations being given and the costs stated.

The industrial uses to which peat charcoal may be applied are considered, ‡ and Stone's inventions for compressing and solidifying peat preparatory to coking are fully described. A coking plant is also illustrated. It is stated that 3 tons of dried peat, when properly treated, will yield 1 ton of charcoal. The charcoal produced from solidified peat has a density of 1·040, and is said to be equal to the best coke made from coal.

Some notes on peat in Ontario have also appeared.§

In Sweden several peat briquetting machines are at work. At Estöf, for instance, there is one, designed by Rode, making 60,000 blocks daily, and on several of the railways peat blocks are used.‖

A. Larbalétrier has just published a small volume, entitled *La Tourbe*, in which he has collected the scanty records dealing with peat previously published, and has supplemented them by his personal observations.

The production and preparation of peat is dealt with at some length

* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xliv. pp. 1333, 1445, 1479.
† *Colliery Guardian*, vol. lxxx. pp. 1127, 1183, 1294; vol. lxxxi. p. 21.
‡ *Ibid.*, vol. lxxx. pp. 1294-1296; twelve illustrations.
§ *Ibid.*, vol. lxxxi. p. 75. ‖ *Engineer*, vol. xci. p. 149.

by Marschick.* He proceeds to show the various applications of peat preparations, and advocates its use as a fuel, as a means of disinfection, as a non-conducting material for prevention of loss of heat, and lastly, in the form of peat-wool, as a surgical appliance for stanching wounds. He also describes the working up of the peat-fibre into cloth materials and paper.

An article has been published by B. Kosmann † on the manufacture of peat briquettes. With a daily production of 125,000 briquettes, the cost of making 1000 briquettes is 2s. 8d. Such briquettes contain 66 per cent. of conbustible constituents, while lignite briquettes contain 70 per cent.

E. Svedmark ‡ discusses the preparation of peat by a Norwegian process.

III.—*CHARCOAL.*

The Manufacture of Charcoal.—Ten charcoal retorts have been erected to supply a blast-furnace at Gladstone, Michigan, by the Cleveland Cliffs Iron Company. The steel shells of the new retorts hold five cords of wood, and are heated externally with coal. As by-products there are stated to be made 3½ gallons of alcohol and 300 lbs. of acetate of lime from each cord of wood, which averages 5000 lbs. in weight.§

A. Bergström ‖ describes a continuous kiln for charcoal or peat.

Ural Charcoal.—Neumark ¶ publishes the following assays of charcoal made in the Ural district, and used in iron smelting:—

	I.	II.
	Per Cent.	Per Cent.
Volatile matter	7·0	13·3
Fixed carbon	85·0	81·5
Ash	1·1	0·9
Moisture	8·0	3·7

Charcoal Briquettes.—G. von Heidenstam ** discusses the manufacture of charcoal briquettes from sawdust. Experiments made at

* *Technische Blätter*, 1899, Series IV., pp. 149–166 ; two plates and illustrations.
† *Glückauf*, vol. xxxvi. p. 933.
‡ *Teknisk Tidskrift*, vol. xxxi. p. 78.
§ *Iron Age*, January 24, 1901, p. 7.
‖ *Teknisk Tidskrift*, vol. xxxi. p. 63.
¶ *Stahl und Eisen*, vol. xxi. p. 110.
** *Bihang till Jernkontorets Annaler*, 1900, pp. 345–360.

Skönvik sawmills have given highly satisfactory results. The average of seventy-five operations showed that the charge was 916·6 kilogrammes, the time occupied in carbonisation was 18·12 hours, and the time occupied by charging and drawing was thirty minutes. The yield per 100 lbs. of briquettes was 33·43 lbs. of charcoal, 8·84 lbs. of tar, and 36·78 lbs. of crude pyroligneous acid. The last-named contains 3·13 lbs. of acetic acid, 0·66 lb. of methyl alcohol, and 0·09 lb. of acetone. The character of the briquette charcoal is shown by the following analysis:—

	Per Cent.
Moisture	9·4
Carbon	80·2
Hydrogen	1·2
Nitrogen	0·36
Oxygen	8·313
Ash	0·52
Phosphorus	0·007

The author gives estimates showing that the manufacture may be conducted so as to yield considerable profit.

IV.—*COKE.*

Beehive Ovens.—A. W. Evans * gives an account of the plant of 101 beehive ovens at Lookout Mountain, in Georgia, used for coal from the Durham seam. The leading dimensions and the charging arrangements are described.

J. P. Brennen † describes the new coke-oven plant of the Eureka Company, in the Klondike region, Fayette County, Pennsylvania. At Leckrone there are 400 beehive ovens, and the Footedale plant also consists of 400 ovens. Electric transmission of power is extensively employed.

R. S. Moss ‡ describes the beehive ovens as used by the Universal Fuel Company at Chicago. The air for combustion may be heated if desired, and is blown into the oven at several points. Also the coal is heated from below by a zigzag flue built in the bottom of the oven.

W. G. Irwin § describes the manufacture of coke, especially in the Connellsville district, with the aid of a number of illustrations, and

* *Mines and Minerals*, vol. xxi. pp. 49-51. † *Ibid.*, vol. xxi. pp. 385-388.
‡ *Ibid.*, vol. xxi. pp. 412-414.
§ *Cassier's Magazine*, vol. xix. pp. 197-206.

shortly traces the history of the industry and the firms engaged in it. Less than one-fifth of the area is stated to be worked out.

Illustrations are given * of the beehive coke ovens and other plant at some of the collieries in Vancouver Island.

Welsh Ovens.—F. Howald † describes the modified Welsh or rectangular coke oven, of which eighty are in use at the Red Ash Colliery in West Virginia. They are 15 feet from back to front, 6 feet wide at the back, and 4 inches wider in front. At the centre of the arch they are 5 feet 10 inches high, and 46 inches high at the sides. The charging hole is nearly 9 feet from the front, which is closed by double doors. A drag placed in the oven before charging is used to draw the coke, the floor being inclined 4 inches to the front. Waste gas is used under boilers.

By-Product Coke Ovens.—G. Blake-Walker ‡ describes the various forms of by-product coke ovens, such as those of Collins, Simon-Carvés, and Otto-Hoffman, &c. The arrangements for recovering the by-products are discussed, and some notes are given on the working of the Simon-Carvés ovens.

W. H. Blauvelt § describes the plant of Semet-Solvay by-product ovens at Wheeling, West Virginia, which is the fifth by-product plant near Pittsburg and also the largest, making 475 tons of 2000 lbs. daily.

The world's production of sulphate of ammonia in 1900 amounted to 493,000 tons, of which quantity Great Britain produced 210,000 tons, Germany 120,000 tons, United States 58,000 tons, and France 37,000 tons. In Great Britain 138,000 tons were obtained in the manufacture of gas, 18,000 tons from blast-furnaces, 39,000 tons from shale, and 15,000 tons from coke ovens.||

Coal-Stamping Appliances.—It has been pointed out ¶ that it is a well-known fact that some badly caking coals can have their coking properties improved by subjecting them to compression before coking, that is, when the presence of separating air spaces is avoided. Some

* *Colliery Guardian*, vol. lxxxi. pp. 458–459.
† *Mines and Minerals*, vol. xxi. p. 11.
‡ *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxlii. pp. 308–320.
§ *Transactions of the Institution of Mining Engineers*, vol. xix. pp. 337–345.
|| *L'Engrais*, February, 1901.
¶ *Stahl und Eisen*, vol. xx. pp. 1248–1254; six illustrations.

improvement certainly does result in this way, and even though the result may not be perfect, yet in many cases a fuel which would otherwise be useless is made available. No accurate scientific investigation has yet been made to ascertain exactly what happens in this case. Indeed the reaction of the coking process generally, and how these are affected by external influences, are still only imperfectly understood. Perhaps in the case of coals low in volatile constituents, the act of bringing the particles of coal closer together by compression enables the available smaller quantity of their distillation products to have a better chance of exerting a binding influence than they otherwise would possess. In the old-fashioned open Schaumburg coke oven this compression was a very easy matter. The coal was simply stamped into the oven. When closed ovens were used, one attempt to attain similar compression consisted in the use of heavy slabs of stone which were allowed to remain on the coal during its coking. Any heavy weight could be used, such as old rails. Other methods proposed consist in rolling or in the use of hydraulic pressure. It has also been proposed to use the ram, employed in pushing the finished coke out of the oven, to compress the coal before this is coked, charging in the coal in small quantities and forcing it against the firmly closed door of the oven. It is now, however, generally agreed that no satisfactory results are to be looked for from the compression of coal within the oven, but that this must be effected outside. The first step in this direction lay in the use of briquettes. Next came the formation, not of a number of small briquettes, but of one large tightly stamped mass of coal, which was then pushed into the oven. Ritter von Merténs put such a method into practice at Trizynietz in Upper Silesia at the commencement of the eighties, and this was subsequently improved by Baumgarten. The sides of the stamping chamber were made of sheet iron, then the bottom was made movable, and the whole placed on a travelling waggon. This was brought before an oven, the coal stamped into it, the movable bottom and the compressed mass pushed into the oven, and the bottom then withdrawn. Quaglio subsequently further modified the method, and his modified form of stamping was subsequently adopted at many works in Upper Silesia. Some illustrations are given of various forms of stamping appliances, and details are given as to the results attained by their use and the working costs. One such appliance of German make stamps the coal, charges it into the oven, and is ready for use at another oven in twenty to twenty-five minutes.

Not only does stamping enable a poorly caking coal to be coked, but it has the further advantage that by its use a considerable percentage of poorly caking coal can be added to ordinary caking coals before they are coked, and still a good coke will result. This addition may reach as much as 50 per cent. The quantity of lump coke, too, that is produced is always several per cent. higher than that resulting from the ordinary methods of coking without compression. In some coals it is necessary to add as much as 15 per cent. of water to a coal. The same coal in its compressed form gives equally good results with 10 per cent. of water. This results in a saving in the gas required for heating purposes, and the large quantities of steam in the gases escaping from the coke oven are considerably diminished. Coals are reduced to about 75 per cent. of their volume by stamping, but the charge in the oven cannot safely be made more than 15 to 18 per cent. more than in the case of the uncompressed coal. A modification in the shape of the oven is possible. These need not be made so conical. Indeed, the side walls might be made parallel to each other. This not only has the advantage of giving a more even working-off of the coke oven charge, but the cost of construction of the oven is lessened. The large number of different shapes of bricks now necessary in many forms of coke oven could be greatly reduced. Another important advantage resulting from the use of compression is that the time taken to charge an oven with the compressed mass is less than in the ordinary system of charging, with the resulting advantage that the vicinity of coke ovens would become less disagreeable, and the health of the work-people also increased. The size of the compressed mass at the Hörde works is about 6 feet deep, 15 inches wide, and nearly 33 feet in length. This stamping has the further advantage that it yields a perfectly homogeneous mass of coal. Machine-stamping needs far less time than does stamping by hand, and is considerably cheaper. It only takes about one-fourth the time to charge the oven, and once pushed in no further rabbling or other treatment is necessary.

The coal-stamping appliance manufactured by Brinck and Hübner, of Mannheim, is claimed by the makers to be the oldest and most widely used machine of this kind.* It is claimed, too, that its construction is the most simple, and that all later forms of coal-stamping appliance have more or less followed this one, so far as the patent permitted. A comparison is drawn between this machine and that of Kuhn, and various advantages are claimed for it. It is driven by the

* *Stahl und Eisen*, vol. xxi. pp. 73–75; one illustration.

aid of an electric motor. Eight machines of this type are in use at the Julienhütte, six at the Donnersmarckhütte, and several at Borsigwerk. In England it is claimed that so far this is the type of machine exclusively employed. Other machines of the Brinck and Hübner type are or shortly will be in use in Westphalia, Moravia, and elsewhere.

F. W. Lürmann * refers to some experiments made by him in the seventies on the application of pressure to coal in the oven, and to a number of patents subsequently taken out.

Coke Pusher.—An illustrated account has appeared of the electrically operated coke pusher used at the ovens at the Adolf von Hansemann Colliery, Dortmund.† A 20-horse-power motor drives the rack pusher so as to expel the coke at the rate of about 30 feet per minute, and the whole machine can be traversed at about double that rate.

An illustration is given ‡ of a coke lorry fitted with an electromotor and trolly pole to dispense with horse haulage.

Ash of Coke made in South Russia.—Neumark § publishes complete analyses of the ashes from fourteen cokes made in South Russia, and also of an anthracite ash. The total percentages of ash in the coke varied from 8·2 up to 25·75 per cent., and the total sulphur from 1·17 to 3·52.

The coke ash contained—

	Per Cent.
Silica	37·92 to 53·50
Ferric oxide	6·94 ,, 32·06
Alumina	19·92 ,, 30·14
Manganese oxide	... ,, 1·07
Lime	1·70 ,, 12·35
Magnesia	0·70 ,, 2·01
Sulphur	0·41 ,, 1·62
Phosphorus	0·04 ,, 0·09

The manganese is taken as Mn_3O_4.

The analysis of the anthracite ash showed 61·67 per cent. of ferric oxide, 29·7 per cent. of silica, 4·73 of alumina, 4·49 of lime, and amongst other constituents 0·93 of phosphorus.

* *Stahl und Eisen*, vol. xxi. p. 75.

† *Iron and Coal Trades Review*, vol. lxi., Supplement, December 21, 1900, pp. 17-18.

‡ *Mines and Minerals*, vol. xxi. p. 46.

§ *Stahl und Eisen*, vol. xxi. p. 110.

V.—*LIQUID FUEL.*

Fuel Value of Petroleum.—W. L. Watts * has given the results of some experiments on the calorific values of Californian oil. The heat units per kilogramme are given as varying from 9688 to 10,788 as compared with 6684 for Nanaimo coal.

Chemistry of Petroleum.—R. A. Wischin † has recently published a work embodying the researches made on the naphthenes which occur in petroleum.

S. F. Peckham ‡ discusses the use of the terms retene, petrolene, and asphaltene in relation to bituminous minerals, and advocates the use of uniform methods and solvents. He also repeats his arguments on the classification of crude petroleums.

B. Steuart § has determined the saturated hydrocarbons present in shale spirit.

D. R. Steuart ‖ discusses paraffin oil and petroleum in regard to their composition and origin, and refers to the possibility of fractionising the oil by filtration through fuller's earth and other materials.

C. F. Mabery ¶ gives an account of the hydrocarbons in Pennsylvanian oil, and of the hydrocarbons and nitrogen compounds in Californian oil. The same author, in conjunction with S. Takano, also describes the hydrocarbons in Japanese petroleum, and in conjunction with W. O. Quayle deals with the sulphur compounds in Canadian petroleum. Together with O. J. Sieplein he has also investigated the chlorine derivatives of petroleums from several countries.

Oil Shale in Scotland.—H. M. Cadell ** describes the geology of the oil shale fields of the Lothians, and of the several well-marked horizons. The lowest is the Burdiehouse, Camps, or Queensferry lime-

* Bulletin No. 19 of the Californian State Mining Bureau, through the *Petroleum Review*, vol. iv. p. 150.

† *Die Naphthene* (Cyklische Polymethylene des Erdols): Brunswick, F. Vieweg & Sohn.

‡ *Journal of the Franklin Institute*, vol. cli. pp. 50-61, 114-124; *Journal of the Iron and Steel Institute*, 1900, No. II. p. 453.

§ *Journal of the Society of Chemical Industry*, vol. xix. pp. 986-989.

‖ *Ibid.*, pp. 989-992.

¶ *Proceedings of the American Association for the Advancement of Science*, vol. xlix. pp. 128-129.

** Paper read before the Edinburgh Geological Society, November 1900; *Iron and Coal Trades Review*, vol. lxi. p. 1048.

stone, which is in the West Calder district, 2400 feet below the Hurlet or Carboniferous limestone, and above which are to be found all the oil shales hitherto worked, with the exception of the shales of Pumpherston, which are situated 600 feet below that landmark. Above this limestone are the Barracks shale, an inferior seam, then the Dunnet, 500 feet higher up, under the Binny sandstone, then the Broxburn shale above the sandstone, and the Fells shale above the marls that cover the Broxburn seams. The Houston coal, with its distinctive green and red overlying marls, forms another very conspicuous landmark all over the district, and above the marl only one seam of value—the Raeburn shale—is to be found. Oil shale is now worked for ammonia as well as oil, and the production of sulphate of ammonia, which has a high agricultural value, forms an important branch of the industry. The lowest seams of shale at Pumpherston are richest in ammonia; and probably the shales richest in ammonia are those in which the proportion of animal to plant remains is greatest, while the shales richest in hydrocarbons, such as those of Broxburn, probably contain an excess of vegetable matter. A geological description is then given in detail of the shalefields of West Calder, Pumpherston, Mid Calder, Broxburn, Philpstoun, Hopetoun, and Dalmeny.

Petroleum in Galicia.—An account by C. Angermann * has appeared of the Sokol-Dominikowice-Kobylanka-Kryg-Libusza oil district in Galicia, with a map of the region. Particulars of the stratification and of the different wells are given.

Petroleum in Hungary.—In an exhaustive description of the geology of the vicinity of Sosmező, in Haromszek County, Hungary, J. Böckh † devotes considerable attention to the petroleum-bearing deposits. Petroleum occurs at three horizons, in the Miocene, in the Oligocene, and in the Lower Cretaceous.

L. Roth von Telegd ‡ gives the results of the borings for petroleum at Zsibo, in Szilagy County, Hungary. Oil was found only in traces, and not in workable quantities.

Petroleum in Roumania.—The occurrence of petroleum in Roumania is described by P. Poni.§

* *Naphtha*, through the *Petroleum Review*, vol. iv. pp. 5, 57, 104.
† *Mittheilungen aus dem Jahrbuche der k. ung. geol. Anstalt*, vol. xii. pp. 1–222.
‡ *Montan-Zeitung*, January 13, 1901.
§ *Annales Scientifiques de l'Université de Jassy*, 1900, pp. 15–148.

C. R. Mircea * describes the Valea Gardului Predeal-Turburea oil region in the district of Prahova, Roumania, in which petroleum of excellent quality has been found.

C. R. Mircea † gives detailed description of the occurrence of petroleum and lignite in the Ramnicu-Serat district. A map of the district accompanies the memoir. E. Baum ‡ discusses the intimate connection between petroleum and rock salt in Roumania; and C. Alimanestianu § deals with the question of the concession of oil lands by the Roumanian Government.

Articles have also been published on the occurrence of petroleum at Berca-Pâclele, in the district of Buzau, by V. Tacit,‖ and on the Glodeni oilfield, in the Dimbovitza district, by R. Sevastos.¶

The Roumanian oil production for the year 1899 to 1900 is given as 224,751 tons, as compared with 182,540 tons in the previous year.**

Petroleum in Russia.—The various proposals that have been made to reclaim some of the land from the sea at Bebe-Aibat, and to drain the Romany Lake into the Caspian, are discussed.††

A short but trustworthy account ‡‡ is given of the great oil fire which occurred at Baku on February 4, 1901.

An investigation has been made §§ into the causes of the recent fire at Baku, and shows that the explosions by which the fire was spread might be caused by the lighter oil burning off, leaving the heavy heated residue to sink into the water at the bottom of the tank, where it generated steam. Or the steam might be formed by the vaporisation of the water mixed in the heavy oil when it burnt. Water should be kept in the bottom of the tank to keep the oil cool.

V. S. Istamin ¶¶ deals with the origin and prevention of fires in the working of oilfields. These fires are frequent, especially in the Bebe-Aibat district, and cause enormous losses. Fires are caused by the friction of the gases rushing out of the mouth of the borehole, by the baler or by ejected stones striking the casing, and by gas from the well taking fire at the furnaces or elsewhere. Heating of the bearings

* *Monitorul intereselor petrolifere Romine*, vol. ii. pp. 472-475.
† *Ibid.*, pp. 355-362. ‡ *Ibid.*, pp. 364-366. § *Ibid.*, pp. 379-390.
‖ *Ibid.*, pp. 497-500. ¶ *Ibid.*, pp. 500-504. ** *Ibid.*, pp. 519-520.
†† *Petroleum Review*, vol. iv. pp. 277-278, 293-294.
‡‡ *Ibid.*, vol. iv. pp. 148-149. §§ *Ibid.*, vol. iv. pp. 378-379.
¶¶ Paper read before the Baku Section of the Russian Technical Society, through the *Petroleum Review*, vol. iii. pp. 499-500.

in the winding machinery may also ignite the gas, so that they should be kept well oiled.

E. H. Foster * describes the pipe line from Michaelova to Batoum. It is 171 miles in length, and has a capacity of 48,000 gallons per hour. An extension of about 90 miles to Ag Taglia is contemplated. Eight-inch steel pipes with screwed joints are used. They were made in Russia and tested under water pressure at 150 atmospheres. There are three pumping-stations, with Worthington compound pumps. These have 21-inch high pressure and 42-inch low pressure steam cylinders, 8½-inch plunger, and 24-inch stroke. The piston speed is 140 feet per minute. Details of the methods of laying the pipes and of testing them, and of the size of the tanks and other details are given, together with a number of illustrations of the district.

Petroleum in Mesopotamia.—A note on the petroleum deposits of Mesopotamia is given by H. Chaouriz.† About 16 tons monthly is produced in the summer at a point about 70 miles north-east of Bagdad from fissures, and several other deposits are known, but none are worked on a commercial scale.

Petroleum in California.—W. G. Young ‡ gives a few general notes on the Coalinga oilfield in Fresno County, California.

According to the same author,§ in the Summerland oil district of California wells are drilled and pumped both on land and under the sea. The district contains in all about 325 producing wells. Nearly two-thirds of these have been sunk on the beach and on the headlands lying immediately back of the shore, the remaining third being submarine wells. Those on the headlands are drilled in the usual way, while those in the ocean are drilled and operated through wharves and trestles extending out into the sea. In all 17 of these wharves have been built, the longest being the Treadwell Pier, which is approximately 1250 ft. in length, about 850 feet of which is occupied by derricks. The field extends about a mile along the shore, 600 feet back from the shore line, and 350 feet seawards. The wells vary from 125 to 500 feet in depth, and the monthly production is about 14,000 barrels.

* *Cassier's Magazine*, vol. xix. pp. 1-16.

† *L'Echo des Mines et de la Metallurgie*, vol. xxviii. p. 54; *Petroleum Review*, vol. iv. p. 101.

‡ *Engineering and Mining Journal*, vol. lxxi. pp. 403-404.

§ *Ibid.*, vol. lxxi. p. 54.

Petroleum in Indiana.—C. K. MacFadden * gives a sketch of the four oil districts in Indiana—the main Indiana Trenton rock district, the Jasper County Carboniferous limestone, the Martin County Loogootee district, and the Terre-Haute district in Vigo County. The first and largest of these covers about 800 square miles, and the oil is similar to that of Ohio. Owing to the laws controlling the waste of gas, many districts have not produced the oil they might otherwise have done. Some of the salt-water wells produce oil in good quantities if they are pumped for a sufficient time. The methods of drilling and of shooting the boreholes and pumping the oil are briefly described, and a short account is given of the three other fields.

Petroleum in Texas.—A large flowing oil-well has been sunk near Beaumont, in the south-east of Texas, so that a third field in addition to Corsicana and Nacogdoches is promised. Oil was struck at a depth of 1300 feet almost without warning. The bottom pipes were violently ejected, and the flow rapidly increased from 250 up to 600 or 1000 barrels per hour about January 16, 1901, when the flow was beyond control. Much of the oil was being saved in an adjacent natural depression in the ground. The oil appears to have a paraffin base and to contain sulphur. A considerable depth of quicksand was encountered.†

According to W. B. Phillips ‡ the flow was controlled and the well finally closed on January 19, or nine days after it began to spout. Some general notes on the oil industry in the State and its prospects are given.

The method adopted by A. F. Lucas § for stopping the flow from the great gusher at Beaumont consisted in lowering an 8-inch pipe over the solid 6-inch stream of oil, and screwing it to the casing. A gate-valve in this pipe was then slowly closed to direct the flow through a side branch 6 inches in diameter. It was then possible to get to the foot of the derrick to put in a solid foundation, to which this pipe was anchored before shutting the valve in the branch-pipe. A. R. Ledoux states that the oil from this well has a specific gravity of 0·925, and also gives the results of fractional distillation.

* *Petroleum Review*, vol. iv. pp. 270, 305, 322, 345.

† *Engineering and Mining Journal*, vol. lxxi. p. 115.

‡ *Ibid.*, pp. 175 176.

§ *Transactions of the American Institute of Mining Engineers*, Richmond Meeting, February 1901.

Petroleum in the Philippines.—It is stated * that the oil industry has developed considerably in the Philippines, and oil is being worked in the islands of Panay, Luzon, Mindanao, Negros, Gimeras, and others. Mostly the oil is found in a strata several feet thick at a depth of about 350 feet. The wells are bored with heavy wooden rods, and are often a foot in diameter. Soapstone is often encountered and worked. The methods of boring and of distillation are crude as a rule.

Methods of Boring for Petroleum.—W. Wolski † describes some new methods of boring, which have, however, not as yet been put into actual practice. Instead of causing the rods as a whole to reciprocate, only the lower section of the rods or the tool itself is given an up and down motion, thereby saving the friction of the rodding in the water. This is done with the water-flush system, using the stream of water to work some form of motor placed close to the tools, so as to drive them directly. In one instance the motor acts like the water-ram used for raising water, the valve being operated by the rush and stoppage of the water.

W. Wolski ‡ discusses the strength of boring-rods and the duration of the blow on the tools, mainly from a mathematical point of view.

W. Osborne § gives a colloquial account of the operation of "shooting" a borehole.

Petroleum Storage in India.—At Budge-Budge, on the right bank of the Hooghly, there are about a dozen large tanks for the storage of Russian and Burmese oil. Their capacities range from 385,000 to 643,000 gallons, and they are built of iron plates varying from $\frac{3}{8}$ to $\frac{1}{4}$-inch in thickness; 6 and 8-inch pipes and pumping plant are provided for filling and emptying them.‖

Burning Petroleum in Furnaces.—A. af Forselles ¶ describes the system of petroleum or masut firing devised by Hjalmar Krusell. This method of firing is rapidly coming into extended use. The

* *Engineering and Mining Journal*, vol. lxxi. pp. 145-146.

† Paper read before the International Congress of Boring Engineers, Frankfurt, through the *Petroleum Review*, vol. iii. pp. 374-375.

‡ *Glückauf*, vol. xxxvii. pp. 213-216; *Petroleum Review*, vol. iv. p. 346.

§ *American Machinist*, vol. xxiii. pp. 846-847.

‖ *Indian Engineering*, vol. xxviii. pp. 373-374.

¶ *Teknisk Tidskrift*, 1900, pp. 79-82; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlix. pp. 89-91.

masut is obtained as a residue on distilling the raw petroleum at a temperature of about 300° C. Its specific gravity is about 0·90 to 0·91, and it takes fire in an open vessel at about 100° to 130° C. On combustion to $CO_2 + H_2O$ it yields 10,500 calories, its chemical composition being about—

Carbon.	Hydrogen.	Oxygen.
87	12	1

In furnace construction it is customary to allow 200 cubic feet of air for the combustion of the pound of masut. Theoretically masut has double the heating power of coal. At the Kolpino Works it was found that for the fusion of 0·48 ton of brass in a reverberating furnace 1·12 ton of coal was necessary, but only 0·368 ton of masut, 1 lb. of the latter thus replacing 3 lbs. of coal.

The process now usually adopted for burning masut in metallurgical works is the new chamber method. In its simplest form this consists of a rectangular space, in the roof of which are placed pipes through which the masut is charged, and with a system of channels in the floor through which enters the air for the combustion. The size of the chamber is naturally dependent on the quantity of masut to be burnt per hour. It has been found in practice that for every 40 lbs. of masut per hour a chamber space of from 12 to 15 cubic feet is necessary. The height of the chamber is a most important matter. It must be at least 3 feet. If it is less than this, the petroleum residues dropping down from the roof will not be completely gasified before they reach the floor. The method of calculating the chamber dimension is given, together with that for the entering air channels and the channel for the combustion products. The temperature in the combustion chamber is placed at about 1200° C. The store vessel for the masut is kept as near as possible to the combustion chamber, but far enough away to prevent the oil heating up to its flaming-point. The residues, after gasification in the chamber just referred to, are completely burnt in the reverberatory or other chamber in which their heat is to be utilised. In a reverberatory furnace it was found that a temperature of 2200° to 2400° was attained in this way, while the temperature in three large muffles placed in this furnace varied from 940° C. to 980° C.

The masut system of firing has one disagreeable objection. This is the formation of coke. To avoid difficulty from this the shape of the gasification chamber has to be so arranged that the air used in the combustion must be made to strike against those points where the coke

is liable to form. This is the spot where the masut strikes against the floor of the chamber from the pipes in the roof. A raised brick floor or bridge at this point, with air inlets beneath it, is one method employed to avoid the coke difficulty.

When the furnace is first lighted it is heated up with wood. When this is well alight the fire door is closed, and a little masut is allowed to drop in. The higher the temperature rises the more masut is charged in, until the ratio between air and masut has become the correct one, and complete combustion results. The larger the furnace the longer must it be pre-heated. One that burns from 80 to 120 lbs. of masut per hour, is usually heated up in three to four hours. The regenerator system is being more and more generally adopted in connection with this system of firing.

E. L. Orde * describes some experiments he has made on different methods of burning oil in furnaces for raising steam. Mechanical steam-jet and air-jet producers were tried, but preference is given to the method of vaporising the oil by heat and then burning the vapour. By distilling the oil, previously heated nearly to the boiling-point by means of steam, the author has succeeded in vaporising all the oil without leaving a carbonaceous residue. From 15 to 16 lbs. of water at 212° C. were evaporated per lb. of oil.

Ozokerite in Galicia.—J. Muck † describes the ozokerite mines of Boryslav in Galicia. With regard to the genesis of the ozokerite he adduced evidence in support of Hoefer's theory. Formerly there was nowhere in Europe where mining was carried on in a more primitive manner. Now, with the introduction of the law of 1898, all is changed. Of the 10,000 small old shafts few are to be seen, and in their place are four large, well-equipped shafts ready to supply the world with ozokerite.

Asphalt.—P. W. Henry ‡ gives some facts relating to the asphalt industry, and *inter alia* describes the Trinidad pitch lake. This deposit has been lowered nearly 4 feet during the past eight years, or at the rate of one inch for 18,000 tons extracted, but borings made by the water-jet method showed that the depth was over 135 feet in the

* Paper read before the North-East Coast Institution of Engineers and Shipbuilders, through the *Engineer*, vol. xc. p. 575.

† *Zeitschrift des Oesterr. Ingenieur- und Architekten Vereines*, vol. liii. pp. 213-214.

‡ *Engineering News*, vol. xlv. pp. 182-186.

centre. It was not possible to bore deeper, as the movement of the material threw the casings out of plumb. The material is dug with picks before dawn, as it is then comparatively brittle, and is loaded into buckets on flat trucks hauled by cable to the end of a wire ropeway on the Bleichert system. The cable tramway is laid on a sort of corduroy road across the surface of the lake. The wire ropeway terminates at a pier 1700 feet long, which gives a depth for shipping of 30 feet. Some of the material is refined on the spot, but most of it is exported in its raw state, containing—

Bitumen.	Water.	Mineral Matter.	Organic, insoluble.
40	28	25	7

The mineral matter is exceedingly fine sand and clay in a state excellently adapted for asphalt paving.

The Bermudez asphalt lake covers about 1000 acres, or nine times the area of that in Trinidad, but in many places it is only 2 to 10 feet in depth. It contains on the average 31 per cent. of water, and 1 to 3 per cent. of mineral matter. It is much softer than the Trinidad material. It is loaded on to side-tipping cars running on a portable track on the lake, and then tipped into railway waggons which carry it to the shipping port, five miles distant, on the Guanoco River. The asphalt deposits of California and other States are also briefly described.

A sketch map is given * of the asphalt district in Venezuela, concerning which there is at present some discussion between the Government of the country and that of the United States. The asphalt is found in a lake, or possibly one or two detached lakes, on the east of the Gulf of Paria. Some of the rivers and creeks run close up to it, so that a short tram line joins one of the mines to the wharf, and a proposed railway will give an outlet direct to the sea. The district is largely mangrove swamp, but is said not to be very unhealthy, and labour is cheap.

VI.—*NATURAL GAS.*

Natural Gas in Bavaria.—During boring operations at Bienwald, in December last year, gas was struck at a depth of 950 feet. In escaping it ignited, and for several days continued to burn, the flames reaching a height of about 33 feet. Analysis shows the gas to contain 80 per cent. of marsh gas.†

* *Engineering and Mining Journal*, vol. lxxi. p. 303.
† *Oesterreichische Chem. Techniker Zeitung*, Jan. 15, 1901, p. 5.

Natural Gas in the United States.—At the close of 1899 there were in the United States 9333 natural gas wells, as compared with 8453 in 1898. The value of the gas produced in 1899 was 20,024,864 dollars, as compared with 15,296,813 dollars in 1898. The value of the gas in Indiana was 6,680,370 dollars, in Pennsylvania 8,337,210 dollars, in West Virginia 2,335,864 dollars, and in Ohio 1,866,271 dollars. The remaining producing States had but small outputs. The average price was 18·5 cents per 1000 cubic feet. *

Natural Gas Tests.—A test was made in the ordinary working of a steel-mill at Pittsburg to determine the relative values of natural gas and of coal. The results are given by A. J. Hollis.† With a 14-inch mill, in five turns, 57 tons were made with a consumption of 272,380 cubic feet of gas, as compared with 39 tons from 470 bushels of coal. In an 18-inch mill the gas consumption was 179,490 cubic feet for 36 tons of steel, and 175 bushels of coal for 17 tons of steel. The average saving in the two cases by the use of the natural gas amounted to about 1s. 4d. per ton of product.

Natural Gas in China.—J. V. B. Murdoch ‡ gives some notes on the brine and oil wells in the province of Szechuan, which are found over an area of about 90 square miles. About seventy wells are said to produce gas which is used for evaporating the brine. The life of a gas well is three to twenty years, and their depth from 2200 to 3300 feet. Wells producing oil are exceptional.

VII.—*ARTIFICIAL GAS.*

Gas-Producers.—A. Wilson § describes several of the forms of gas-producers now in use, and deals at some length with the use of gas for obtaining power by the means of gas-engines, of which many forms are illustrated and described.

F. J. Rowan ‖ gives plans and some illustrations of the Duff producers and ammonia recovery plant, which has been at work for about two years, gasifying 500 tons of slack weekly.

* *Stahl und Eisen*, vol. xx. p. 1067.
† *American Manufacturer*, vol. lxviii. p. 13.
‡ Paper read before the Institution of Mining and Metallurgy, May 15, 1901.
§ *Journal of the West of Scotland Iron and Steel Institute*, vol. viii. pp. 135–156.
‖ *Iron and Coal Trades Review*, vol. lxii. pp. 68–70.

F. J. Rowan * deals with producer gas and its application. The rationale of gas production is first discussed on general lines, after which the history of the subject is briefly considered. Special attention is given to the Duff producer plant. The composition of fuel gas is then considered, and some description is given of the Wilson, Dawson, and other producers. The methods of removing impurities and recovering by-products from the gas are then discussed, diagrams of several plants being given. The applications of gas for firing different types of furnaces is then dealt with, with the aid of a number of sections of furnaces.

Illustrations have been published † of the Duff gas-producers and their by-product recovery plant at Widnes.

Illustrations are given ‡ of the Fraser-Talbot gas-producer, which has a conical bottom and water-seal, central blast, and a mechanical stirrer. The latter consists of a vertical shaft carrying two arms, one horizontal and the other inclined. The shaft and arms are water-cooled, and are given a combined rotary and vertical motion by means of gearing which is designed to allow for slip or cessation of the vertical movement if a large and hard piece of clinker is encountered. The producer has two feeding hoppers with Bildt or other automatic feed.

Dimensioned sections of the Morgan gas-producer and a photograph taken on the charging-floor of a row of them to show the Bildt automatic charging apparatus have appeared. § The producer is of barrel section internally, the largest diameter being 10 feet, and it has a water-seal bottom and a central air and steam supply. Some tests showed—

CO_2.	CO.	H.	Steam Pressure.	Depth of Fuel Bed.
			Lbs.	Feet.
7·2	22·1	13·7	8·8	4·05
6·1	24·2	14·1	10·7	4·07
6·5	24·9	16·6	15·3	4·33
6·0	25·0	16·6	8·1	4·33

In a week's work 8·4 to 8·8 lbs. of coal were burnt per square foot per hour, and 164 lbs. of coal were used per ton of steel heated.

* *Iron and Coal Trades Review*, vol. lxii. pp. 124, 186, 397, 500, 713, 923.
† *Engineering*, vol. lxxi. pp. 41–43.
‡ *Iron Age*, February 14, 1901, pp. 8–9.
§ *Ibid.*, January 17, 1901, pp. 12–13.

G. Velleman * discusses continuous and intermittent producers working on water gas. The treatment is largely mathematical.

The preparation, uses, and hygienic significance of water-gas are discussed by P. Roeseler.† The paper contains a brief bibliography of the subject.

Mond Gas.—H. A. Humphrey ‡ discusses the use of power gas in large gas-engines for central station purposes. The Mond producer plant at Winnington in Cheshire is taken as the gas plant, being shortly described, and then the use and cost of the method is dealt with.

A. Rollason § deals with the manufacture of Mond gas in central stations, and its application to the coals in Staffordshire. Other particulars of the Mond gas scheme for South Staffordshire have appeared. ||

The Mond plant at Trafford, near Manchester, is also illustrated.¶

VIII.—*COAL-MINING.*

The Uses of Boreholes in Coal Mining.—An account is given ** of the various uses to which boreholes can be put in collieries, and references are given to the original sources, in which these uses are more fully described. In the Wyoming Valley boreholes are put down ahead of the workings to show where the quicksand of the alluvial covering is too near the roof. Boreholes are used in several districts for draining gas from old workings, and are best employed when blowing fans are at work; with exhaust fans they are not of much use. They are also used in advance of the workings for draining gas or water. Moving ropes for endless or other rope haulage are carried down boreholes; steam pipes and water pipes are laid in them, or compressed air pipes. Culm flushing for filling old workings and for extinguishing fire is well known as carried on through borings. When the borehole

* *Les Gazogènes continus et discontinus*, Lyon, 1900.

† *Vierteljahrsschrift für öffentliche Gesundheitspflege*, 1900, p. 410.

‡ *Proceedings of the Institution of Mechanical Engineers*, 1901, pp. 41-247.

§ Paper read before the South Staffordshire Iron and Steel Institute, February 9, 1901.

|| *Engineer*, vol. xci. pp. 287, 309.

¶ *Colliery Guardian*, vol. lxxxi. p. 740.

** *Engineering and Mining Journal*, vol. lxx. pp. 699-700.

passes through solid rock it need not be lined, and may be used as a rising main for the pumps. If the rock is defective the cracks may be filled in with cement.

Illustrations have appeared * of an arrangement by which drilling rods are suspended from the end of the boring bar by means of a strong spiral spring.

Shaft Sinking.—H. C. Cole † describes the Sandwell new sinkings at West Bromwich, South Staffordshire, where the thick coal was struck at a depth of 330 yards. It is here 6 feet thick, in the neighbourhood of the Oxhill fault, and the heathen coal, 3 feet thick, is immediately below. An inset was made at a depth of 347 yards, and a heading is being driven to the west to meet the coal. A Hathorn-Davey compound pumping-engine lifts 6000 gallons hourly from a lodge 135 yards down the shaft. The pump and boilers are described, and a short account is given of the sinking and hauling engines.

W. Washington ‡ describes the deepening of the shafts from the Barnsley seam to the Parkgate seam without interfering with the winding of coal at Mitchell Main Colliery.

J. L. C. Rae § gives an account of the sinking of the Sydney Harbour Collieries.

According to F. Laur,‖ the deepest shaft in France is the Arthur de Buyer Pit of the Ronchamp Collieries, which was completed in November 1900. Its depth is 3312 feet, and its internal diameter is 13 feet. It is walled from top to bottom, and has 295 feet of cast iron tubbing. The sinking, walling, and installation of the tubbing and guides has occupied sixty months. The rock temperature is 10·5° C. at a depth of 10 yards, and 47·5° C. at the bottom. The sinking has been carried out under the direction of Poussigue.

E. Wéry ¶ describes the Portier method of repairing pit tubbings. This consists in the injection of slow-setting cement very finely ground and diffused through water into the space behind the tubbing.

An illustrated description is given ** of the methods employed for

* *Engineering and Mining Journal*, vol. lxx. p. 733.
† *Journal of the British Society of Mining Students*, vol. xxiii. pp. 35–42.
‡ *Transactions of the Institution of Mining Engineers*, vol. xx. pp. 146–149.
§ Engineering Association of New South Wales; *Colliery Guardian*, vol. lxxxi. pp. 233-235.
‖ *Echo des Mines*, vol. xxvii. p. 1443.
¶ *Revue Universelle des Mines*, vol. li. p. 295.
** *Iron and Coal Trades Review*, vol. lxi. pp. 941-943.

deepening the No. 2 shaft of the Rhein Elbe and Alma Colliery below the fourth level at a depth of 388 yards without interfering with the ordinary winding. An electric hoist was placed at the third level, and used to raise the spoil to the fourth level, where it was transferred in the tubs to the ordinary winding apparatus, the lower parts of the shaft being protected by scaffolding. A suspended electric pump was used for dealing with the water. Illustrations of the appliances with full particulars of them are given.

Stegemann * publishes an account of the sinking of a new shaft at the Maria Collieries, near Aix-la-Chapelle. The shaft was 13 feet in diameter, and was intended for ventilation as well as winding. The first part of the boring, to a depth of about 2000 feet, offered no particular difficulties, but the Upper Tertiary layers contained so much water that it was decided to solidify the strata by freezing them. To this end a circle of holes, 24 in number and about 9 inches in diameter, were bored all round the workings, into which the freezing pipes, 4 inches diameter, were lowered; inside these again were placed the brine pipes, of 1 inch internal diameter. The brine was forced down into the latter by a pump on the surface, and returned through the annular space between the larger and smaller pipes; it was then led into the cooling vessel of the refrigerator, and again circulated through the pipes. The cooling agent employed was carbonic anhydride, expanding from 80 to 15 atmospheres. It was possible to resume boring operations within four months from the time of putting down the freezing plant, and the work was then completed without further hindrance. Full details of the operations are published.

A long account of a sinking by the freezing process has been published.† Especial attention is given to the fracture of the brine pipes.

Winding Appliances.—D. Burns ‡ shows how the weight of the winding drum affects the power and time of winding, and gives illustrations of two large drums, of which one is built of mild steel with an openwork structure to reduce the weight.

H. Hall § gives some notes on the use of electro-motors for winding at a small colliery in the St. Helen's district. The current is obtained from a local tramway company.

* *Glückauf*, vol. xxxvii. pp. 1-5.
† *Annales des Mines*, vol. xviii. pp. 379–484.
‡ *Transactions of the Institution of Mining Engineers*, vol. xx. pp. 49–54, 154–156.
§ *Transactions of the Manchester Geological Society*, February 1901.

J. Horner * illustrates a number of portable and fixed hoisting engines driven by steam, electricity, and compressed air, and used for different purposes.

S. F. Walker † describes various forms of apparatus used for the prevention of over-winding, especially Bertram's visor, the Lymm and Critchley apparatus, and two appliances used at St. Etienne. Various suggestions are made, and it is proposed that the power at present wasted in braking should be utilised by being converted into electric energy, which would be available to aid the next wind.

K. Habermann ‡ describes the Wodrada controller for winding-engines.

Illustrations are given § of the appliances used at St. Etienne for applying the brakes and reversing the engine to guard against over-winding.

An illustration is given ‖ of a 25-ton Ormerod safety-hook, and of the bell used with it.

Illustrations are given ¶ of the barriers used at Montrambert Colliery.

Illustrations are also given ** of the steel pit headgears at Deep Navigation pit, Treharris, at Lamb pit, Cramlington, and at Hazlerigg Colliery, Northumberland.

W. Müller †† defends the Koepe system of winding. The first installation of this character was put in operation in the Ruhr coal-field at the Hanover Colliery on September 3, 1877, but it is only within the last ten years that the method has been extensively adopted. In tabular form details are given of the installations at twenty-five shafts.

The Koepe winding plant at Sneyd and at Walsall Wood Collieries and also at a German colliery are described, with the aid of illustrations. ‡‡ The arrangement and construction of the pulleys and the advantages and disadvantages of the system are dealt with at some length. The Whiting endless rope system is then described, and also

* *Cassier's Magazine*, vol. xix. pp. 492–505.

† *Proceedings of the South Wales Institute of Engineers*, vol. xxii. pp. 121–131.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlix. pp. 227–228; *Colliery Guardian*, vol. lxxxi. p. 966.

§ *Colliery Guardian*, vol. lxxxi. pp. 68–69.

‖ *Iron and Coal Trades Review*, vol. lxi. p. 1101.

¶ *Ibid.*, vol. lxi. p. 1168.

** *Ibid.*, vol. lxii. p. 871.

†† *Glückauf*, vol. xxxvii. pp. 258–264.

‡‡ *Engineer*, vol. xci. pp. 181–183, 366–367.

Marshall and Hopwood's traversing guide-pulleys for preventing the angling of the rope wound on wide drums.

W. S. Gresley * proposes to replace winding machinery by an adaptation of the man engine. Automatic appliances would be used to transfer the tubs from one set of platforms to the other.

Winding Ropes.—F. H. Probert † gives some notes on the testing of winding ropes in the duchy of Anhalt in Germany, where very strict regulations are in force. A spare rope must be kept hanging in the shaft, and the cage must be hung on it for twenty-four hours before winding. Special tests must be made before use and at frequent intervals. The guides and ropes are inspected every fortnight. For testing the strength of the rope a length of about a metre is cut out near the cage end, and each wire is tested separately in tension and in torsion. Any wire which is 20 per cent. under the average tensile strength is neglected. The sum of the remainder is then divided by the working load when winding ore or men, and should give safety factors over six and over ten respectively. Any wires which have failed to pass the torsion tests are also neglected in making the calculation. A rope may not be used more than three years without special permission. The results of a large number of tests are appended.

Underground Haulage.—J. F. Lee ‡ gives a full description of the underground rope haulage at Glapwell Colliery, where the rope is worked on the tops of the tubs in the steepest part of the workings and below the tubs elsewhere. A number of tests were made from which the coefficient of friction for full tubs was determined as 1 to 56, and for empty tubs 1 to 30.

A. T. Thomson § describes the haulage at Manvers Main Collieries, where the ropes for the main and auxiliary lines are worked by electromotors.

N. M. Thornton ‖ describes the endless rope haulage at Pelton Colliery.

S. J. Routledge ¶ describes a method of working an underground incline with a number of branches by means of a so-called loose "tail-

* *Proceedings of the South Wales Institute of Engineers*, vol. xxii. pp. 79–85.
† *Transactions of the American Institute of Mining Engineers*, August 1900.
‡ *Transactions of the Institution of Mining Engineers*, vol. xix. pp. 110–118.
§ *Ibid.*, vol. xx. pp. 29–34. ‖ *Ibid.*, vol. xx. pp. 195–201.
¶ *Mines and Minerals*, vol. xxi. p. 141.

rope." This rope is hitched to the loaded tubs at the branch and to the full set at the end of the main haulage, and is dropped at both ends when the tubs from the branch reach the collecting point. An empty set is then attached to the end of this rope, and runs back.

Some sketches are given of the brakes, pulleys, and other appliances used on a self-acting incline at Aldwarke Main Colliery, near Rotherham, Yorkshire, for lowering twenty-four tubs, each holding 10 cwt., at a time.*

Sketches are given of the old and new forms of haulage roads used at the Whitehaven Collieries, where extensive improvements are being made.†

A method of calculating the proportions between the gradient and length of inclines and the load moved and the speed attained is given.‡

W. W. Core § discusses the methods of placing the rope sheaves on curves.

F. O. Solomon ‖ deals with the feeding of horses, with especial reference to colliery studs. The composition, digestibility, and quantity of food required are described, and the substitution of one kind of food for another is discussed.

H. K. Myers ¶ gives the weight of electric locomotives running at six to eight miles per hour, with intermittent load, as 400 lbs. for each horse-power rating of the motors, and the weight should be eight times the rated draw-bar pull, regardless of the speed. If the work is continuous, these weights may be reduced 25 per cent. Tables are given showing the size, current used, draw-bar pull, and other details of the ordinary sizes on various gradients, and the characteristic curves of one machine is given. The method of calculating the size is shown, and the use of electric locomotives generally, and the conditions of the permanent way and other details, are discussed. The author has also ** dealt with compressed air locomotives on similar lines.

Illustrations of two electric locomotives for mining use, one constructed in 1889 and the other of the latest form, are given †† for the sake of comparison.

J. S. Cunningham ‡‡ describes the haulage methods in use at Wind-

* *Iron and Coal Trades Review*, vol. lxi. p. 1343.
† *Ibid.*, vol. lxii. p. 823.
‡ *Mines and Minerals*, vol. xxi. pp. 284-286.
§ *Ibid.*, vol. xxi. pp. 270-271.
‖ *Transactions of the Institution of Mining Engineers*, vol. xix. pp. 279-293.
¶ *Mines and Minerals*, vol. xxi. pp. 226-227.
** *Ibid.*, pp. 188-190.
†† *Ibid.*, vol. xxi. p. 208.
‡‡ *Ibid.*, vol. xxi. pp. 340-341.

ber Colliery in Somerset and Cambria Counties, Pennsylvania, and gives a plan of the workings, which are on the single entry system. Six electric locomotives are at work, and each hauls 250 to 350 tons daily.

W. B. Clarke * gives some practical notes on the choice and on the working of electric locomotives.

Electricity in Mines.—E. H. Hewlett † discusses the uses of electric transmission of power in mines, and contrasts alternating with continuous current systems. The plant at Mount Morgan mine in Australia is described.

W. Wendelin ‡ gives descriptions of electric power installations in operation at various collieries. Some notes on the application of electricity to the different branches of the mining industry are published.

C. T. de Tolentino § discusses the application of electricity to mining.

A supplement to the *Iron and Coal Trades Review* ‖ deals with recent progress in the application of electricity to coal-mining operations. Electrically driven fans, hoists, winding and haulage engines, drills, &c., are first dealt with. E. K. Scott then discusses electric haulage, showing how to calculate the size of the motor required, and giving details of the sizes and costs for main and secondary haulage. E. D. Phillips deals with the economy of the application in collieries and steel works, and the subject is also discussed by J. E. Hodgkin. A description is given of the three-phase plant at Park Collieries, Garswood, Lancashire, and elsewhere. Pumping plant is also described for the Planitz Colliery, Zwickau, and a number of illustrated descriptions of electric locomotives are appended.

The electric power and lighting plant at Ackton Hall Colliery, near Pontefract, is described, with the aid of a number of illustrations. Parsons steam-turbines, coupled direct to the dynamos, are extensively used.¶

An illustrated account is given ** of the electric equipment of the

* *Mines and Minerals*, vol. xxi. pp. 389–391.

† *Transactions of the Australasian Institute of Mining Engineers*, vol. vi. pp. 226–247.

‡ *Bulletin de la Société de l'Industrie Minérale*, vol. xiv. pp. 1081–1127.

§ *Revista Minera*, vol. lii. pp. 229–230.

‖ Vol. lxi., December 21, 1900.

¶ *Colliery Guardian*, vol. lxxxi. pp. 179–181.

** *Electrical World*, 1900, pp. 846–847; *Iron and Coal Trades Review*, vol. lxi. pp. 999–1002.

Sneyd Colliery, Burslem. The generator at present employed is a ten-pole, 50-kilowatt, three-phase current Westinghouse machine, and it supplies current for pumping and hauling.

Some illustrations have appeared * of electrically driven air-compressors, made at Ipswich, for use in the workings of collieries. It is considered that they may be used with advantage, as the power is readily taken into the mines without the expense of a long length of pipes for compressed air, and can be converted so as to drive the drills or other machinery.

S. F. Walker † discusses the cost of a horse-power at a colliery, and shows the various items entering into the consideration.

J. P. Jackson ‡ discusses the use of electric transmission of power in collieries, and especially its application to electric locomotives and coal-cutting machinery.

J. E. Hardman § gives a number of illustrations of the application of electricity in an article on the practical management of mining operations.

F. C. Perkins || describes the electric generating plant at Essen on the Ruhr, consisting of three 1000-kilowatt and two 500-kilowatt alternators, giving current at 5000 volts. The boilers are heated by gas from coke ovens at a neighbouring mine.

The electric installations at the Adolf von Hansemann Colliery at Mengede are described by R. Goetze.¶

O. Gähring** describes the electric power station at the Emma brown coal-mine at Streckau. The waste gases from the distillation of the brown coal are used for driving gas-engines that generate the electric current.

A recent report by H. C. Jenkins †† deals with the utilisation of brown coal on the spot where it is mined as a source of power for transmission to a distance by electrical means, with special reference to the transmission to Melbourne from Gippsland. Except for pumping, the mining of the brown coal would not present much difficulty, and the fuel might be gasified in producers and the gas used for raising

* *Iron and Coal Trades Review*, vol. lxi. p. 1109.
† *Journal of the British Society of Mining Students*, vol. xi. pp. 93–101.
‡ *Journal of the Franklin Institute*, vol. cli. pp. 29–50.
§ *Engineering Magazine*, vol. xx. pp. 665–684.
|| *Iron Age*, March 21, 1901, pp. 1–2.
¶ *Glückauf*, vol. xxxvi. p. 1029, with three plates.
** *Ibid.*, vol. xxxvii. pp. 410–414.
†† Department of Mines, Victoria, 1900.

steam. The cost of the electric plant, including the line wires, would, however, be so great that the method cannot compare with that of carriage by rail, which at present is about one penny per ton-mile.

Compressed Air in Mines.—C. Jüngst * describes in detail the compressed air plant at the Camphausen Colliery, Saarbrücken. On opening up the colliery in 1872 compressed air was used for driving the rock drills used for shaft sinking. For this purpose a wet compressor made by Humboldt was installed, and is still in operation. Later, in 1886, a small dry, quick-running compressor by Klein, Schanzlin, and Becker, of Frankenthal, was installed as a reserve, but after a few years was discarded. In 1895 a second wet compressor, made by the Dingler Company, of Zweibrücken, was procured. The compressed air, originally used only for drills, is now employed for pumping, winding, and ventilation. The cost of the compressed air plant amounts to £8, 11s. 9d. a day. In order to do the same amount of work by hand power 267 workmen would be required, the daily cost of which would be £33, 7s. 6d., or 3·89 times that of the compressed air plant.

H. G. Morris † describes the d'Auria air compressor, which is of the direct-acting type without fly-wheels, the steam and air pistons being mounted on the same rod. A device which may be regarded as a development of that used in the Worthington pump is used to compensate for the differences in steam and air pressures at the beginning and end of the stroke. This consists of a third piston centrally placed on the common piston rod, and working in a cylinder of which the ends are connected by a pipe forming part of the foundation plate. The cylinder and pipe are kept filled with liquid.

W. Stewart ‡ has successfully used cast-iron brackets built into the walling of the shaft for holding a line of 6-inch pipes for the conveyance of compressed air in a shaft 275 yards in depth. These brackets replaced byats.

Mine Dams.—F. Mládek § describes various mine dams lately erected in the Przibram Mines. These he divides into two main divi-

* *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xlviii. p. 491–503.

† *Transactions of the American Institute of Mining Engineers*, Richmond Meeting, February 1901.

‡ *Proceedings of the South Wales Institute of Engineers*, vol. xxii. pp. 132–134, with plate.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlix. pp. 117–119; five illustrations.

sions, (1) those in which water had to be dammed back in cross-cuts, and (2) in the damming off of spaces to be used as large reservoirs for compressed air. The first of these is again subdivided into three divisions. In the unused cross-cuts or other workings dammed off to act as compressed air reservoirs, the air is compressed to four or five atmospheres, and then used for driving the drills, pumps, &c.

Rock Drills.—An illustration * is given of the Nancy electric rock drill. It is driven by a small rotary electromotor, and has a frictional feed.

F. Schember † describes the Triumph rock-drilling machine of the Ruhrthal Company. This is of simple construction, and various advantages are claimed for it.

Explosives and Blasting.—A. Larsen ‡ discusses the use of liquid air for explosives. When the cartridges are made on the spot where they are to be used, by soaking or mixing carbonaceous material with the liquid air good results may be obtained, but the life of the cartridge is very ephemeral, and a reliable standard of strength cannot be obtained.

The use of accumulators in firing cartridges in blasting is described by J. von Lauer, § who observes that in 1896 he described the various kinds of electric igniting methods as applied to blasting in fiery mines. In this he showed that the low tension method was the best, and that it can be used almost without any especial precautions. At that time only the galvanic form of this method was considered, but this is unsatisfactory, and the author now describes the use of accumulators for this purpose. The use of the dynamo for this purpose is also referred to. The author claims that the accumulator method is a very satisfactory one in many respects, although experiments are likely to lead to a still further improvement.

J. von Lauer ‖ deals with blasting by electric firing devices, and points out the advantages of the high tension method of firing. The apparatus is independent of weather conditions, and can, without much previous preparation, effect the instantaneous firing of a mine.

* *Engineer*, vol. xc. p. 562.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlix. pp. 17–19; four illustrations.

‡ *Transactions of the Institution of Mining Engineers*, vol. xix. pp. 164–170.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. pp. 537–539.

‖ *Ibid.*, vol. xlviii. pp. 641–644, Figs. 1–3, Plate XX.

The battery also requires little repair, and the changing of single elements can be performed by anybody. On the other hand, it is attended with the disadvantage that when a large number of shots have to be fired at once, the battery assumes such unwieldy proportions that the handling of it becomes a matter of difficulty. To overcome this drawback he constructed an apparatus consisting of accumulators instead of primary batteries for producing the current. The construction and the method of operating are fully described. It is stated that by this means a hundred shots can be fired simultaneously, and that energy sufficient for producing a total of 10,000 ignitions can be stored in the accumulator cells. A spark-tester forms a principal feature of the apparatus, by means of which the condition of the charge in the accumulator can be ascertained at any time. The weight of the apparatus complete is 11 lbs.

T. Rasmussen * describes an expanding drill bit for chambering the ends of boreholes.

Coal-Cutting Machinery.—A series of articles on coal-cutting machinery has appeared. † The first deals historically with the subject, and then the advantages are discussed, especial reference being made to the higher proportion of round coal obtained, and the increased price for the product. The difficulties encountered in the adoption of machinery are then dealt with, after which the evolution of the machine is traced with the aid of Bunning's diagrams of the early types, and some later forms are more fully illustrated.

Some particulars are given by J. Gerrard ‡ of the use of coal-cutting machinery in Great Britain. Altogether there are 197 compressed air machines and 57 electric machines, and their total outturn is estimated at 3,538,408 tons. Yorkshire is the largest user. The cost and other details of working thin seams are also given.

F. C. Swallow § gives some notes on the opening out of coal royalties by the Stanley heading machine. With a machine cutting a circular heading 7 feet in diameter, the average advance was 6·1 yards daily, yielding 24½ tons of coal.

A. Bachellery ‖ describes the use of coal-cutting machinery in

* *Transactions of the Institution of Mining Engineers*, vol. xx. pp. 186–187.

† *Colliery Guardian*, vol. lxxxi. pp. 20, 67, 123, 182, 231, 287, 347, 399, 462, 518, 568, 623, 735, 791, 851, 904, 959, 1017.

‡ *Iron and Coal Trades Review*, vol. lxii. p. 494.

§ *Journal of the British Society of Mining Students*, vol. xxiii. pp. 57–66.

‖ *Bulletin de la Société de l'Industrie Minérale*, vol. xiv. pp. 1129–1173.

American collieries, and discusses the advantages of the different types of machines. Most of them are adapted for stall workings, as long-wall workings are rare in that country, and they are considered in four classes: wheel cutter machines, percussive machines, cutter bar machines, and chain cutter machines. The second and fourth types prevail, and it may be considered that air-driven percussive machines and electrically driven chain machines are practically the only ones which will hold the field in the future. Between them it is evidently difficult to draw a balance, as they are adapted for such differing conditions, but the relative advantages are discussed in some detail, and the power absorbed by electric machines is dealt with.

In 1900 A. de Gennes,* at the instigation of the French Minister of Public Works, made an exhaustive study of the methods of coal-mining by machinery in the United States. He visited the mining districts of Illinois, Ohio, and Pennsylvania, and in his report states that the number of companies using machines has increased from 51 in 1891 to 287 in 1898, and he estimates the number of machines now in use at 2622, as compared with 545 in 1891. About 20·5 per cent. of the total tonnage raised in the collective mining regions in 1898 was mined by machinery. The cutting machines most generally in use are those of the percussive type, the Harrison, the Ingersoll-Sergeant, and the Sullivan, all of which are driven by compressed air. The only example of an electrically driven machine with percussive action is the Morgan-Gardner. A brief description is given of each type, with some comments. A rotary wheel machine, and various forms of chain machines are mentioned, and particulars of their work are given.

H. F. Bain † describes the Lee coal-cutting machine for long-wall workings as used in America. It has a bar cutter which can be turned on a vertical pivot, so that it can be placed parallel to the face, and turned into the coal at starting. A spiral steel band carrying the teeth is wound on the bar, and can be readily renewed. The machine is driven by a 15 horse-power electro-motor, and undercuts 30 inches.

Illustrations are given ‡ of a Jeffrey shearing machine, with a chain cutter, driven by an electro-motor.

J. J. Rutledge § gives a short description of the Appanoose County coalfield in Iowa, where the seam is about 2½ feet in thickness, and

* *Annales des Mines*, vol. xviii. pp. 217–248; three plates.
† *Transactions of the Institution of Mining Engineers*, vol. xix. pp. 144–152.
‡ *Engineering and Mining Journal*, vol. lxxi. p. 436.
§ *Mines and Minerals*, vol. xxi. pp. 345–346.

fairly level at a depth of 140 feet. Several varieties of pillar and stall working are in use, and a large number of different coal-cutting machines are successfully employed.

A list of the coal-cutting machines that have been introduced into France during the past year has been published.* The details are as follows:—

Colliery.	Machines.
Bruay	4
Marles	7
Lens	5
Courrières	7
Dourges	3
Decazeville	5
Campagnac	2
Roche-la-Molière	1
Carmaux	7
Grand' Combe	10
Graissessac	9

K. Glinz publishes † an illustrated description of an electric coal-cutting plant of the percussive type, designed and constructed by Siemens & Halske in 1895 for the Altenwald Mine, near Saarbrücken. Particulars of the four years' working are given, and the results are summarised in tabulated form. An interesting comparison is made with other types of coal-boring machines, with regard to their performances and power requisite for driving them.

C. Zalman ‡ and J. Wázlavik state that at the Bettina Colliery, in the Dombrau district, an Ingersoll coal-cutting machine, at the time they wrote, had been in constant use for some six months. They describe the results attained by its use, first describing the machine and its mode of erection, and then passing to the method of working adopted. The undercut made is from 43 to 51 inches deep. Before the use of this machine was introduced hand working was employed. A direct comparison between the two was therefore possible, and this showed that the work done by the aid of the machine was 2·63 times as much as when hand labour was in use. The relative costs for hand labour and machine were 3s. 7½d. and 3s. 5d. per foot. They were consequently in favour of the machine. This was rarely found to need repairs, but when these are required a workman who under-

* *Echo des Mines*, vol. xxviii. p. 422.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xlviii. pp. 464–489.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. pp. 587–591; three illustrations.

stands the construction of the machine should be employed. To prevent the rapid wear of the indiarubber tubing attached to the machine it should be covered at close intervals with wooden rings connected together with wire. Other slight improvements found desirable are referred to. On the whole the authors conclude that while the use of the machine does not effect any marked saving in expenditure as compared with hand labour, yet its use enables a much higher output to be obtained in the same time.

Methods of Working Coal.—N. M. Thornton * describes the long-wall methods of working seams from 3 to 5 feet in thickness in the Eastwood district, Nottinghamshire.

D. A. Willey † describes the mining of soft coal in America in the States of Alabama, Maryland, and West Virginia, and discusses the reasons for the growing export. A number of illustrations are appended.

J. T. Beard ‡ discusses the character of the seams as affecting the adoption of different varieties of the pillar and stall and the long-wall methods of working coal in Iowa. The leading dimensions of the working are given.

J. E. Strong § describes the single entry method usually employed in Alabama.

Mine Drainage.—A new form of pump has been designed by H. Ashley, and has come into use. The working barrel is closed at the lower end, but has a lantern opening in the middle. The working bucket fits the barrel above and below this opening, and its intermediate hollow trunk contains a large number of inlet valves. On the top of the bucket is a double beat valve. During the down stroke the water, which is trapped in the bucket and barrel by the inlet valves, passes through the double beat valve to be lifted on the next upstroke. All the valves are thus mounted in the bucket so that they can easily be withdrawn, a feature of considerable value. ||

H. Davey ¶ discusses the compounding of Cornish engines and illustrates those designed by him and used at various places.

* *Transactions of the Institution of Mining Engineers*, vol. xix. pp. 125–129.
† *Cassier's Magazine*, vol. xix. pp. 430–442.
‡ *Mines and Minerals*, vol. xxi. pp. 126–127.
§ *Ibid.*, p. 195.
|| *Engineer*, vol. xc. p. 587, with illustrations.
¶ *Transactions of the Institution of Mining Engineers*, vol. xix. pp. 153–163.

E. Bainbridge * describes the electrically driven Hatfield pump for underground use. In this pump three cylinders are placed radially, and the pistons are worked direct from the motor shaft, having the very short stroke of about one inch.

Binder † discusses electrically driven pumps for mine drainage, and gives some general observations as to the best means to secure a reduction in the number of revolutions in electric motors for driving such pumps.

The latest addition to the series of volumes on mechanical engineering at the Paris Exhibition, published by Dunod, is a treatise on pumps, covering 86 pages, with 143 illustrations, from the pen of R. Masse.

With the aid of numerous drawings, F. Frölich ‡ describes the Kaselowsky-Prött hydraulic pumps. In tabular form, details of thirty pumping plants constructed on this system are given.

The question of the centralisation of the pumping power of the mines of the Ruhr district § began to receive attention some thirty years ago, and committees were subsequently appointed to investigate, and make suggestions on the matter, but the difficulty of securing the concerted action of companies, who were rivals in commerce, prevented the carrying out of any effective scheme. Since the formation, however, of the Coal Syndicate of the Rhine and Westphalian Districts, by which interests, formerly conflicting, are now united, the question of centralised mine drainage is being revived.

Face to face as the Syndicate finds itself with annually increasing working costs, it becomes necessary to look round and study in what department economies may easiest be effected. It is stated that for every 300 feet deeper that a shaft is driven, the consumption of fuel for driving the pumps is increased 1 per cent. The greater depth involves besides an increased capacity of the plant itself. For every ton of coal raised about 4½ tons of water are pumped, the annual cost of mine drainage throughout the whole Ruhr district, including upkeep of plant, being estimated at over £250,000.

This forms the chief unproductive outlay incurred in working the mines, and it is obvious that any efforts towards reducing working costs might with advantage be directed to the centralisation of the whole pumping power of the district, instead of splitting up the

* *Engineer*, vol. xix. pp. 346–351.
† *Bergbau*, 1900, No. 11.
‡ *Glückauf*, vol. xxxvi. pp. 1053–1065.
§ *Berg- und Hüttenmännische Zeitung*, vol. lix. pp. 607–609.

performance of this colossal task among a number of disconnected units. Instances are cited where such an arrangement has worked for some years with exceedingly beneficial results.

A. Padour * describes the pumping appliances at the Bruch Collieries in Northern Bohemia. Large quantities of water have to be raised from several shafts. The plant includes a spraying arrangement for laying dust and cooling the air.

G. Leugny † describes the adit level from the Ernest Biver pit at Gardanne to the seashore near Marseilles. Endless rope haulage is used for dealing with the spoil, and a Ser fan provides the ventilation. In parts the level is lined with iron tubbing and in parts with concrete. Sections are given to show the form adopted in the different clays and limestones encountered.

The Ventilation of Collieries.—J. W. Hutchinson ‡ describes the working of the Waddle fans at Bamfurlong Colliery, where two 30-foot fans work on branch drifts from the same upcast shaft, and are driven by a single engine. With the two fans running, about 45 to 50 per cent. more air is passed than with a single fan. These fans and a 35-foot fan at another shaft have replaced furnace ventilation.

J. W. Robinson § describes the Guibal fan, and some tests made with it.

In an account of the South Hetton coal companies' collieries, some illustrations are given ‖ of the radiators used for heating the air in the downcast shaft in the winter time, to prevent the formation of ice.

J. Hart ¶ describes a method of building concrete stopings. In one case where suitable stone was not available, broken coal was used with success in a stoping 70 feet in area and 15 inches in thickness. Three barrels of cement and six barrels of sand were used.

A. Hübner ** points out that in most of the deep and fiery collieries of Northern Bohemia, ventilation has to be most carefully effected, and the main ventilation doors, &c., are made as strong and lasting as possible. The worked-out chambers, too, have to be most carefully

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlix. pp. 77–82, with plate.

† *Revue Technique*, through the *Colliery Guardian*, vol. lxxx. p. 913.

‡ *Transactions of the Manchester Geological Society*, January 1901.

§ *Journal of the British Society of Mining Students*, vol. xxiii. pp. 102–106.

‖ *Iron and Coal Trades Review*, vol. lxii. p. 237.

¶ *Mines and Minerals*, vol. xxi. p. 237.

** *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlix. pp. 115–117, three illustrations.

separated off from the actual workings. A modified pillar and stall method of working is in use. Powerful air currents are employed, and plenty of water is used in sprinkling. The use of wood for partitions for walling-off old workings was first introduced at the Johann brown-coal mine in Northern Bohemia in 1893, after brick, stone, &c., walling had been found unsatisfactory. The author now describes and illustrates the various ways in which this has been replaced by wood, and the uses to which this has been put. Wood is most useful where there is any pressure.

Fire-damp Explosions.—Illustrations are given of Petit's automatic apparatus for taking samples of the air in the mine at regular intervals, for the purpose of fire-damp determinations. This appliance has been used in the St. Etienne Collieries since 1895. *

Another diffusion apparatus for detecting fire-damp, designed by H. G. Prested, is stated † to have been tested with success at Pentre Colliery in the Rhondda Valley. The diffusion pressure into a porous pot, acting on a flexible diaphragm, completes an electric circuit.

A description is given ‡ of a device, introduced at Witkowitz, for effecting the automatic closure of the subterranean dynamite magazine, in the event of fire-damp explosions.

W. N. Page § gives a plan of the Red Ash Mine in West Virginia, together with some account of the explosion which occurred there in March 1900. Suggested rules for fire bosses are appended.

A somewhat extensive occurrence of explosive gas in some old metal-mine workings which had been long abandoned is described by F. W. Grey.‖ At the Hutti Mine in the Deccan, old workings 340 feet deep were struck, and the gas which came out exploded. Decomposed timber and animal matter were found.

A. H. Rogers ¶ gives an account of an occurrence of fire-damp in some metal-mines in Mexico, near Villaldama. The gas is ascribed to the rotting timber in old workings.

An article has been published ** dealing with the principal explosions in the Prussian collieries in 1889. The explosions discussed in

* *Colliery Guardian*, vol. lxxxi. p. 124. † *Ibid.*, vol. lxxxi. p. 966.

‡ *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1900, p. 252.

§ *Transactions of the American Institute of Mining Engineers*, Canadian Meeting, August 1900.

‖ Paper read before the Institution of Mining and Metallurgy, February 20, 1901.

¶ *Engineering and Mining Journal*, vol. lxxi. pp. 488-489.

** *Zeitschrift für das Berg- Hütten- und Salinenwesen im preussischen Staate*, vol. xlviii. pp. 504-507.

detail occurred at the Preussen Colliery on July 1, and at the Reden Colliery on September 16. In each case plans of the workings are given.

A detailed account of the fire-damp explosion at the Consolidation Colliery at Schalke on March 7, by which 18 miners were killed, has been published.*

Rock Temperatures at Sydney.—J. L. C. Rae,† E. F. Pittman, and T. W. E. David, give very full records of the rock temperatures observed at Sydney Harbour Colliery, Balmain, Sydney, New South Wales, between the depths of 600 and 1100 feet, together with a full geological section of the strata encountered. The rate of increase was fairly low, being 1° F. for every 90·7 feet. At Cremorne, Sydney Harbour, the increase in a borehole was 1° F. in 80 feet.

The Lighting of Collieries.—S. F. Walker‡ deals at some length with electric lamps for miners' use. Those worked with primary and those with secondary batteries are considered, their difficulties and advantages are discussed, and the question of cost is also entered into, after which the author refers to the danger of explosion. Practically this is zero with electric lamps, as explosions have only been produced under conditions which could never occur in practice.

T. V. Simpson§ describes the safety-lamp cabin recently built at Heworth Colliery, with accommodation for cleaning and dealing with 1200 lamps.

Fähndrich‖ gives the results of his experiments made with a view to ascertain the best dimensions for safety-lamp gauzes.

L. Volf¶ gives a series of statistics showing the causes of fire-damp explosions. Unsafe safety-lamps had much to do with these. The earlier experiments relating to the testing of safety-lamps are briefly referred to, and the subject is dealt with historically. The author now describes his Schondorf apparatus for the testing of safety-lamps in use at the Johann Colliery, Karwin.

Coal Dust.—The arrangements for dealing with the coal dust at the Anna and Carl pits of the Cologne Mining Company, at Altessen,

* *Glückauf*, vol. xxxvii. pp. 389–391, with one plate.

† *Journal and Proceedings of the Royal Society of New South Wales*, vol. xxxiii. pp. 207–224.

‡ *Journal of the Institution of Electrical Engineers*, vol. xxv. pp. 815-856.

§ *Transactions of the Institution of Mining Engineers*, vol. xx. pp. 17–19.

‖ *Glückauf*, vol. xxxvi. p. 1009, with two plates.

¶ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlix. pp. 4–10, with sheet of illustrations.

are described by Winkhaus.* At the Anna pit there are 15,688 metres of water pipe and 91 working places. At the Carl pit there are 19,028 metres of water pipe and 114 working places. The cost of the installation was as follows:—

	Pipes.	Reservoir.
Anna	£1790	£111
Carl	2190	490

Accidents in Mines.—The report † of the four inspectors of mines appointed by the Home Secretary to investigate the methods of preventing falls of roof adopted at the Courrières Collieries in France has been issued in the form of a Blue-book of twenty-six pages. The inspectors state that the system of supporting the roof at the Courrières Collieries may be divided into two parts—viz. (*a*) systematic timbering, with the timber inserted as soon as there is room for it; (*b*) the use of temporary iron bars to support the roof in advance of the last "setting" of timber until there is room for another "setting." They quite believe that the Courrières system, if rigidly applied, would result in the prevention of a large proportion of the accidents by falls which might otherwise occur. The inspectors add that, though it was no part of their mission to make a general study of the methods of mining in the Pas-de-Calais, they could not help being impressed by many excellent arrangements for the safety and welfare of the workmen, both at Courrières and at Lens. They were also much struck by the neatness and order which prevailed everywhere, and the excellent cottages and gardens for the workmen.

C. Le Neve Foster ‡ also deals elsewhere with the methods of preventing fall of roof at the Courrières Collieries. Much discussion has ensued.

H. F. Bulman § also gives some notes on the Courrières Colliery.

E. Reumaux ‖ describes the H-iron bars used at the face in the Lens Colliery.

D. J. Evans ¶ gives some notes on the methods of cutting and setting timber in collieries.

* *Glückauf*, vol. xxxvii. pp. 189–194.

† March 20, 1901.

‡ *Transactions of the Institution of Mining Engineers*, vol. xx. pp. 164–175.

§ *Journal of the British Society of Mining Students*, vol. xxiii. pp. 87–92.

‖ *Ibid.*, pp. 206–212.

¶ Paper read before the Indiana Mining Institute; *Mines and Minerals*, vol. xxi. pp. 39–40.

Leybold * deals with the accidents caused by falls of roof and sides in the Dortmund coalfield. He describes in detail 100 fatal cases that occurred in the months of January to July 1900. Of these 69 were due to falls of rock and 31 to falls of coal.

T. K. Adams † compares the coal production and number of accidents with their causes in different coal-mining districts of the United States. Especial reference is made to Pennsylvania, which occupies a favourable position. The incapacity of many of the miners and the lack of discipline is strongly condemned as a cause of many accidents.

F. L. Hoffman ‡ gives tabulated statistics of accidents in the different States of America for the last ten years. The average rate of fatal accidents is 2·64 per 1000 men employed, but it has varied between 2·3 and 3·3. Curiously enough the rate is the same, 2·64 per 1000, for railway employees.

In consequence of the recent disastrous dynamite explosion at Aniche, in France, the Minister of Public Works has issued a circular, according to which it has been decided that in future the quantity of dynamite kept in the issuing store-rooms above ground is never to be in excess of that required for daily use, and that the subterranean magazines and stores are never to be filled during working hours.

J. R. Godfrey § deals generally with safety appliances and precautions necessary in mines. Reference is made to machinery, boilers, winding appliances, shafts, timbering, explosives, &c.

Rescue Appliances for Collieries.—The modified pneumatophore of Desgrez ‖ and Balthazard appears to be a considerable advance on the steel bottle containing liquid oxygen. In this modified form sodium peroxide is used in connection with water as the generating agent for the air charged with carbon dioxide, the excess oxygen of the sodium peroxide passing into the air, and the carbon dioxide in the latter combining with the soda of the soda solution.

J. von Lauer ¶ describes various forms of life-saving apparatus for

* *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xlviii. pp. 563–634.

† Paper read before the Western Pennsylvania Central Mining Institute; *Mines and Minerals*, vol. xxi. pp. 53–55.

‡ *Engineering and Mining Journal*, vol. lxx. p. 608.

§ *Transactions of the Australasian Institute of Mining Engineers*, vol. vi. pp. 1–33.

‖ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. p. 568.

¶ *Ibid.*, vol. xlviii. pp. 511–515, with plate.

use in mines. The necessity for safety breathing appliances is becoming more and more recognised, and the author sketches the progress made in this direction since the earlier efforts of the eighteenth century, when the necessity for better ventilation began to be thoroughly understood and dealt with.

M. J. Shields * calls the attention of coal-miners to the use of first-aid packets and first-aid societies founded on the methods of the St. John's Ambulance Association.

The History of Coal-Mining.—R. L. Galloway † has continued his annals of coal-mining and the coal trade to the nineteenth century, and in the first articles of the series the period between 1836 and 1850 is dealt with.

The earliest notices of the exportation of coal from England occur in the records of Newcastle-upon-Tyne and in the Royal Proclamations and other State papers relative to that town. The first direct reference to the subject which has been found is contained in the Rolls of Parliament, 1325, 19 Edward II. In 1546 Henry VIII. sent orders to the Mayor of Newcastle to forward 3000 chaldrons of coal to France, and the trade with that country thereafter increased to such an extent that petitions were made against it. In the Journals of the House of Commons, February 1563, mention occurs of a Bill to restrain the carriage of Newcastle coals over sea. In July of the same year an Act was passed in Scotland to prevent the exportation of coal, as thereby great dearth of fuel had been occasioned.‡

Some notes on the history of coal-mining, especially in the present century, have appeared.§ Portraits of men who have contributed to the advance in the industry are given, together with a number of illustrations of early appliances and methods.

E. W. Hassler ‖ gives a short but interesting sketch of the origin and development of the coal industry in Pittsburg.

Mine Surveying.—The calculation and plotting of mine surveys by the co-ordinate method has been much facilitated by the publica-

* *New York Medical Journal*, September 8, 1900; *Mines and Minerals*, vol. xxi. p. 207.

† *Colliery Guardian*, vol. lxxx. pp. 874, 981, &c.

‡ *Law Journal*; *Globe*, May 11, 1901.

§ *Iron and Coal Trades Review*, vol. lxii. pp. 27, 75.

‖ *American Manufacturer*, vol. lxviii. pp. 294–295.

tion of compact and inexpensive traverse tables by H. Louis * and G. W. Caunt.

The methods of surveying mines with the hanging compass in the presence of iron are discussed by O. Brathuhn,† and various forms of shifting-heads for centering mine theodolites are described by J. Adamczik.‡

M. Przyborski § has successfully employed magnalium, an alloy of aluminium and magnesium with 10 to 15 per cent. of magnesium, in the construction of mine-surveying instruments. The alloy gives as good results as brass and weighs two-thirds less.

A. Larson ‖ gives some useful hints on plumbing mine shafts, on stands for surveying instruments, and on sighting in narrow passages.

E. Sánchez y Lozano,¶ of the Madrid School of Mines, describes and illustrates an ingenious theodolite he has invented. The instrument is a tacheometer with concentric telescope. Vertical angles are measured by means of a graduated arc.

H. P. Seale ** describes the method of contouring on mining properties with the aid of the tacheometer.

H. D. Hoskold †† gives an extensive series of notes on ancient and modern surveying and surveying instruments, books, tables, &c. The history of the subject is traced, illustrations are given of many of the earlier and later forms of instruments, and the bibliography of the subject receives attention.

A compact instrument for rapidly and accurately determining the strike and dip of mineral deposits has been devised by Leyendecker.‡‡

Leo Gluck §§ has designed an apparatus known as "Gluck's Vein Projector," by means of which the inclination of dips, intersection of veins, &c., in mines can be quickly calculated and determined without the aid of mathematical formulæ. It is claimed that much time is saved in the study of mine plans by the use of this instrument. Diagrams are given and problems worked out, which show its application to the surveying of mines.

* *Traverse Tables.* London: Arnold, 1901.

† *Zeitschrift für Vermessungswesen*, 1900, p. 186.

‡ *Ibid.*, p. 100.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlix. p. 241.

‖ *Teknisk Tidskrift*, vol. xxxi. pp. 26–30.

¶ *Revista Minera*, vol. li. pp. 553–554.

** *Transactions of the Australasian Institute of Mining Engineers*, vol. vi. pp. 62–86.

†† *Transactions of the Institution of Mining Engineers*, vol. xix. pp. 171–240.

‡‡ *Glückauf*, vol. xxxvii. p. 72.

§§ *Mines and Minerals*, vol. xxi. pp. 193–195; eight illustrations.

An illustration is given of Van Slooten's miner's compass.*

F. Norris describes a form of miner's dial.†

Mine Management.—F. Danvers Power ‡ gives some hints for assisting those who have to order mine stores, and shows the method of keeping the accounts. Very full lists of the material and apparatus required are given, and, where possible, the ordinary sizes or particulars are added. Special reference is made to Australian practice.

A. G. Charleton § discusses the general principles of successful mine management, and also methods of office organisation, cost-keeping, and records of work.

Descriptions of Collieries.—Detailed descriptions have been published of a number of collieries.‖ Amongst others, G. E. J. M'Murtrie gives a detailed description of the Newdigate Colliery near Nuneaton.

R. L. Watson ¶ gives a brief account of the collieries on Vancouver Island, with especial reference to those worked under the harbour at Nanaimo.

J. L. C. Rae ** describes the Sydney Harbour Collieries at Balmain. The first boring showed a seam 7½ feet thick at a depth of 2801 feet, but the coal was charred by dolerite dykes, so another boring was made with the result of the present sinkings. Two shafts 18 feet in internal diameter are sunk.

W. T. Heslop has described a number of the Natal collieries and gives illustrations of some of them.††

Descriptions have been published of the following French collieries :—Lens (*Colliery Guardian*, vol. lxxx. p. 1045) ; Lievin (*Colliery Guardian*, vol. lxxx. p. 1095) ; Douchy (*Colliery Guardian*, vol. lxxx. p. 1149) ; Roche la Molière et Firminy (*Colliery Guardian*, vol. lxxx. p. 1253) ; Bessèges (*Colliery Guardian*, vol. lxxx. p. 1368) ; Saint-Etienne (*Colliery Guardian*, vol. lxxxi. p. 35).

An interesting point, showing the recognition of the connection

* *Engineering and Mining Journal*, vol. lxxi. p. 149.

† *Transactions of the American Institute of Mining Engineers*, Montreal Meeting.

‡ *Transactions of the Australasian Institute of Mining Engineers*, vol. vi. pp. 124–225.

§ *Engineering Magazine*, vol. xx. pp. 235–246, 685–702.

‖ *Journal of the British Society of Mining Students*, vol. xxiii. pp. 43–48.

¶ *Mines and Minerals*, vol. xxi. pp. 249–251.

** Paper read before the Engineering Association of New South Wales ; *Colliery Guardian*, vol. lxxx. p. 1202.

†† *Industries, South Africa ; Colliery Guardian*, vol. lxxxi. pp. 479, 515, 648, 740.

between satisfactory work in the mines and a satisfactory home life of the collier, is mentioned in connection with the collieries of the Ruhr district. Here the workpeople often had to pay away their wages as they got them to shops, from which they had purchased in advance on credit all their household needs. These supplied poor goods at high prices. To meet this, workmen's co-operative stores were established, and to free the workpeople from their financial bondage to the shopkeepers, the various colliery managements advanced wages up to £5 to their employees so as to enable them to free themselves from their other debts, and to start afresh. Other matters in which some action of the kind was also taken are referred to, the housing question being one of them.*

The Norton mines in Virginia are described by R. Fleming.†

The Curtis lignite mine in Colorado is described by A. Lakes.‡

The Cleveland No. 4 Colliery, near Chariton, in Iowa, is described.§

F. Meade || describes the Pictou Collieries in Colorado, where three seams, 7 feet, 4 feet, and 5 feet 10 inches in thickness, separated by 32 feet and 12 feet of sandstone, are worked through inclines.

R. A. Randall ¶ gives an account of the colliery at Saginaw, Michigan, where 1200 tons are wound daily in four shafts.

A. Dinsmore ** deals with the various collieries in La Salle County, Illinois.

L. C. Morganroth †† describes a small anthracite mine in Pennsylvania owned and worked by two men with very primitive appliances. One man worked underground, and the other ran the breaker and other surface machinery, occasionally throwing a lump of shale at the motive power—a horse—to keep it moving.

A description has appeared ‡‡ of the Hazel Mine at Canonsburg, Washington County, Pennsylvania.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. pp. 419–421.
† *Mines and Minerals*, vol. xxi. pp. 289–290.
‡ *Ibid.*, p. 298.
§ *Engineering and Mining Journal*, vol. lxxi. pp. 361–363.
|| *Mines and Minerals*, vol. xxi. pp. 1–3.
¶ *Ibid.*, pp. 100–101.
** *Ibid.*, pp. 145–147.
†† *Ibid.*, vol. xx. p. 494.
‡‡ *Engineering and Mining Journal*, vol. lxx. pp. 728–730.

IX.—*COAL-WASHING AND SCREENING.*

Screening Coal.—J. E. O. Keefe * describes the banking and screening arrangements at Choppington Colliery, Northumberland. The tipplers are in line with each other on one road, so that the first tub from each deck of the cage passes straight through the first tippler to the second, and carries the empty tubs on in front. A jigging-screen with two screening surfaces one over the other divides the coal into three classes. The round coal passes straight on along picking-belts with pivoted loading-ends, while two transverse belts lead away the other sizes.

At one of the South Hetton collieries the Murton movable trough washer is in use. The belt is 60 feet in length, 3 feet wide, and 8 inches deep, with 2-inch stops every 3 feet. It is placed on an inclination of 1 in 18. Some plans of the plant are given.†

Illustrations are published ‡ of the surface plant at the Hazel Mine, Canonsburg, Pennsylvania, to show the screening and loading arrangements.

W. G. Irwin § gives an illustration of the Ottumwa appliance for loading railway waggons as used at a colliery at Listie, near Somerset, in Pennsylvania.

H. S. Poole ‖ gives the result of washing certain Cape Breton coals. With 50-ton samples of coal from the mines mentioned, the percentage results were as follows :—

	Raw Coal.		Washed Coal.	
	Ash.	Sulphur.	Ash.	Sulphur.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Hub	7·50	3·24	4·37	2·38
Caledonia	15·00	3·02	7·05	2·87
Stirling	11·09	4·23	5·50	3·12
Gowrie	11·55	5·26	6·01	3·15

* *Journal of the British Society of Mining Students*, vol. xxiii. pp. 51–52, with two plates.

† *Iron and Coal Trades Review*, vol. lxii. pp. 238–239.

‡ *Colliery Guardian*, vol. lxxxi. pp. 86–87.

§ *Engineering and Mining Journal*, vol. lxxi. p. 527.

‖ *Transactions of the Nova Scotian Institute of Science*, vol. x. pp. 245–247.

Coal from the Dominion Coal Company gave the following results:—

	Raw Coal.	Washed Coal.	Coke from Washed Coal.
	Per Cent.	Per Cent.	Per Cent.
Moisture	2·10	1·97	9·16
Volatile matter	31·00	33·21	1·86
Fixed carbon	56·83	60·00	88·98
Ash	10·07	4·82	9·16
Sulphur	2·38	1·79	1·62

An account is published* of the coal conveying plant recently erected for the Dominion Coal Company by the Robins Conveying Belt Company. The installation is said to be the largest of its kind in the world, the carrying capacity being 750 tons per hour over a horizontal distance of 1000 feet. The storage bins contain each 10,000 tons.

A brief description, accompanied by illustrations, appears of several types of coal screens and washers constructed by Popineau, Vizet & Company.† The screens are cylindrical in form, and are set at a slight inclination to the horizontal. The space between the bars is increased towards the lower end. The cylinders are caused to rotate by means of cranks and bevel gearing.

George H. Evans ‡ gives some useful practical hints on the construction of ditches and pipe-lines for conveying water to mining localities. Some examples of sluices are illustrated.

Handling Coal.—J. D. Twinberrow § discusses the capacity of railway waggons as affecting the cost of transport. Much attention is paid to the loading and unloading of coal, and illustrations are given of various plants for the purpose in this country and in America.

Some account has appeared ‖ of the arrangements for handling coal at the Liverpool Docks, and, as a contrast, the proposals of seventy years ago are shown in the reproduction of an old illustration.

J. H. Apjohn ¶ discusses various forms of coal handling and load-

* *Engineering and Mining Journal*, vol. lxx. p. 763; three illustrations.

† *Revue Industrielle*, 1900, pp. 482-483.

‡ *Mines and Minerals*, vol. xxi. pp. 202-203; two illustrations.

§ *Institution of Mechanical Engineers' Proceedings*, 1900, pp. 557-616, with eleven plates.

‖ *Iron and Coal Trades Review*, vol. lxi. pp. 1349-1353.

¶ *Indian Engineering*, vol. xxix. pp. 206-207; *Colliery Guardian*, vol. lxxxi. p. 964.

ing plant, and describes the Brown hoists used at the Kidderpore Docks.

The Wrightson coal shipper is illustrated.*

Illustrations are given † of the steel trestle works and hoppers for lifting and storing coal for coke ovens at Everett, Massachusetts. The total weight of steel amounts to 166 lbs. for every ton of coal stored.

F. S. Snowdon ‡ gives a number of illustrations of vessels used on the Great Lakes for the transport of coal, and other illustrations of docks and coal loading appliances there and elsewhere.

E. H. Coxe § describes the methods used in Virginia for lowering the coal from the mines to the railways by single and double inclines, and of lowering the tubs themselves, or by emptying them first into a larger truck. Shoots are also mentioned.

An illustration is given of the coal handling plant at Skagway in Alaska. ‖ It consists of a trestle girder 125 feet long, mounted on wheeled towers running along the wharf, and provided with rope haulage gear for the baskets.

Illustrations are given by W. Fawcett ¶ of the Brown hoists used at some of the United States coaling stations for the navy.

J. G. S. Hudson ** describes the wire rope-way at Port Morien, Cape Breton, for taking the coal from the mines to the storage bins on the loading pier.

An illustration has appeared †† of the coal dock of the Dominion Coal Company at Cape Breton. Conveyors capable of handling 750 tons of coal per hour over 1000 feet are provided in addition to the appliances for emptying the railway trucks.

Briquettes.—Some account has appeared of the manufacture of briquettes in New Zealand ‡‡ from brown coal with admixture of pitch.

* *Iron and Coal Trades Review*, vol. lxii. p. 923.

† *Engineer*, vol. xci. pp. 422-426.

‡ *Engineering Magazine*, vol. xx. pp. 157-172.

§ *Mines and Minerals*, vol. xxi. pp. 10-11.

‖ *Engineering and Mining Journal*, vol. lxxi. p. 151.

¶ *American Manufacturer*, vol. lxviii. pp. 131-132.

** *Transactions of the American Institute of Mining Engineers*, Montreal Meeting.

†† *Engineering and Mining Journal*, vol. lxx. p. 763.

‡‡ Report of the Mine Inspectors; *Iron and Coal Trades Review*, vol. lxi. pp. 1340-1341.

PRODUCTION OF PIG IRON.

CONTENTS.

I.—*BLAST-FURNACE PRACTICE.*

Blast-Furnace Tuyeres.—J. M. Hartman * ascribes many of the failures of bronze water-cooled tuyeres to the insufficient use of the pricker rod for keeping the air passage open into the crucible. In consequence the blast does not penetrate properly into the charge, and molten iron and slag trickle over the metal of the tuyeres, heating it so that oxidation, and finally cutting readily take place. In some cases this is due to the area of the tuyere being too large, or to an unequal distribution of pressure. A velocity of entering air of 20,000 feet per minute is required for anthracite; for coke it is 15,000 feet, and for charcoal 10,000. Twelve months is a good life for a tuyere. In case of obstruction a small cartridge is sometimes pushed into the clinker in front of the tuyere.

A form of cast iron holder for a bronze bosh plate is illustrated.†

Charging Blast-Furnaces.—W. Kennedy ‡ uses an automatically operated valve, worked by a ram on the hoisting engine, to cut off the steam near the end of the lift, so that the speed of the charging-skip is rendered more uniform as it approaches the bell.

F. W. Lürmann § describes the hoist for blast-furnace charging purposes designed by E. G. Rust. This consists of a narrow inclined plane designed for two waggons, one of which is discharging at the top of the incline, while the other is being charged at the bottom. The waggons are made to pass half-way up one beneath the other.

* *Iron Age*, February 21, 1901, p. 7. † *Ibid.*, p. 16.

‡ *Iron Trade Review*, January 10, 1901, p. 16.

§ *Stahl und Eisen*, vol. xx. p. 1147, two illustrations; *Journal of the Iron and Steel Institute*, 1900, No. II. p. 494.

Experiments in smelting Gellivare A-ore and concentrates in the blast-furnace are described by H. Tholander.*

Blast-Furnace Repairs.—F. Müller † observes that at the Düdelingen ironworks there were in 1899 six blast-furnaces in blast, having a total production of 650 tons of pig iron. Of these, four had open throats, but were provided with Darley gas take-offs. It was desired, however, to equip a central electric station, and to work this with blast-furnace gas. An adequate quantity of gas had therefore always to be available. It was decided, therefore, to close two of the furnaces, so that there should be four closed-top furnaces available, and side by side. The author now describes how this change was effected, and the operations that it involved. The blast-furnaces were at the same time put into thorough repair. The costs of these various operations are given. In the case of each furnace they averaged about £1275.

Westphalian Coke in the Blast-Furnace.—The total production of coke at all the collieries in the Ruhr coalfield amounted in 1900 to 9,644,157 tons. The production of coke in the Saar and Aix-la-Chapelle districts amounts to about 1,400,000 tons. There has of late been a rapidly growing outcry against the deterioration in the quality of the Westphalian coke. This has not received due attention on the part of the manufacturers, and attention is drawn ‡ to it. Complete returns are given of all the coke delivered to a large West German works in the second half of 1898 and in the same period of 1900. In the former period 146,270 tons were delivered, and in the latter 137,055 tons. The ash and moisture determinations showed—

	Second Half of 1898.		Second Half of 1900.	
	Ash.	Moisture.	Ash.	Moisture.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Maximum	11·20	6·88	10·81	11·78
Minimum	8·01	5·59	9·64	7·83
Average	8·90	6·39	10·22	10·50

* *Jernkontorets Annaler*, vol. lv. pp. 493–532.
† *Stahl und Eisen*, vol. xxi. pp. 4–6; two illustrations.
‡ *Ibid.*, vol. xxi. pp. 212–213 and 291–293.

These data refer in each case to seventeen deliveries, the results being given for each of these. It will be seen that in the second half of 1898 the average ash contents was 8·90, while in the same period of 1900 it had risen to 10·22. Again, while the moisture was only 6·39 per cent. on the average in 1898, it was 10·5 per cent. in 1900. It is generally accepted that to evaporate the water and to slag off the ash about an equal quantity of carbon is necessary. Calculating on this basis, the disposable carbon of the 1898 coke was 69·22 per cent., but only 58·56 per cent. in 1900, or equivalent to an increase of 4·67 shillings in the price of the ton of coke, with this at 25·2 shillings. As a matter of fact, the books of the blast-furnace works in question show that 0·116 ton more coke was used to produce the ton of pig iron in 1900 than was necessary in 1898. The quality of the pig iron, too, was less satisfactory despite the increase in the quantity of coke, and the production was about 10 per cent. less, the coke being soft and badly burnt. The extra costs of the ton of pig iron, as a consequence of the bad quality of the coke, were therefore as follows :—

	Shillings.
0·116 ton coke at 25·2 shillings	2·92
Increased wages and increased consumption of materials	1·44
Manganese lost through bad quality of coke . . .	0·16
Total . . .	4·52

To this has to be added increased costs in connection with the conversion of the pig iron into ingot iron. It is shown that the cost of the ton of ingots is increased by 7·11 shillings, the various details making up this increase being given seriatim.

A series of results are given from a number of other works. These show :—

WORKS II.

Year.	Ash.	Moisture.
	Per Cent.	Per Cent.
1893 . . .	8·76	4·76
1896 . . .	9·91	6·60
1900 . . .	10·00	10·10

The details for the other intervening years show a steady rise in the total percentage of ash and water :—

WORKS III.

Year.	Ash.	Moisture.
	Per Cent.	Per Cent.
1887 . . .	7·02	8·22
1900 . . .	10·51	10·26

Similar results are shown for eight other works. In all of these there was a steady and serious rise in the percentages of ash and moisture. Incidentally attention is drawn to the way this latter should be determined. A sample of only a few grammes often taken for this assay in laboratory practice may readily give too low a result. At one works a whole waggonful, 0·2 ton in weight, is taken from the heap, rapidly broken down, well mixed, and an iron box containing about 11 lbs. is filled with this, weighed, and allowed to stand in a space heated by waste steam for one or two days. Reliable results are obtained. The moisture in coke varies enormously, even in the same kind of coke, according as more or less water is used in quenching it. In one and the same sort a maximum of 33 per cent. may be found, or only a minimum of 5 per cent., consequently only an average result derived from a number of determinations can give a result approaching accuracy. Most coke is unfortunately like a sponge, and if much water is used in quenching it, a large quantity will be retained by the coke.

Blowing Engines. — An elevation, plan, and sectional elevation have been published * to show the dimensions of the new blowing engine at the North-Eastern Steel Company's Works, Middlesbrough. It is of the vertical cross-compound type, with the steam cylinders placed over the blowing cylinders. The high pressure cylinder is 48 inches diameter, and the low pressure 90 inches diameter, the two air cylinders being 90 inches diameter; the stroke of all is 6 feet. The engine will deliver 52,000 cubic feet of air per minute at a pressure of 15 lbs. per square inch, with a steam pressure of 70 lbs., and a vacuum of 10 lbs. per square inch, at a speed of fifty revolutions per minute. It is of ample strength in all parts for a steam pressure of 100 lbs. per square inch, and a corresponding increase in blast pressure. At this pressure it will indicate about 3800 horse-power.

Some illustrations of recent forms of blowing engines, especially of the valves, have appeared.† They include the steam valve of the Buckeye engine, Hoerbiger and Rogler's suction, and other valves for various sizes of engines, and the air valves of a blowing engine at the Youngstown Works.

F. W. Gordon ‡ gives some illustrations of part of a single-acting

* *Iron and Coal Trades Review*, vol. lxi. pp. 1352–1354.
† *Ibid.*, vol. lxii. pp. 609–610.
‡ *Iron Age*, October 18, 1900, pp. 1–6.

cylinder for a blowing engine driven by two gas-engines with blast-furnace gas. The cylinder is 72-inch bore and 28-inch stroke. It is driven at 160 revolutions, the gas-engines being placed at opposite ends of the flywheel shaft, and having alternate explosions, or one for each compression. A pair of balanced inlet valves are worked from an eccentric set at 88°, while the crank shaft and the outlet valves, also balanced, are worked from an eccentric at 60° in advance of the crank. They are thus opened when the cylinder pressure is at 6 lbs., though the air reservoir pressure is 12 lbs. Each valve is 18 inches in diameter. The piston speed is 747 feet per minute.

W. E. Snyder * gives a short historical sketch of the blowing engine, and deals with the compression of the air as shown by indicator diagrams. A number of sections and other illustrations of various forms are given, and the details of construction are discussed. Vertical engines of various types are chiefly employed, and there are but few horizontal engines, though, in the author's opinion, they are much to be preferred, as being more convenient and accessible.

A method devised by a German firm for the lubrication by means of graphite dust is described.†

Pig Breakers.—Some illustrations giving the front and back views of Croasdell and Hall's pig breaking machine, and of the crane arrangement for transferring the comb, have appeared.‡ This machine is in use at several works in Great Britain, and it is of the type having breaking rams operated by eccentrics.

Pig Iron Casting Machines.—Plans have been published § of the pig casting machine designed by E. Ramsay, of Birmingham, Alabama. It is of the rotary table type. One of its special features is the pouring device, which consists of a horizontal drum with radial holes mounted over the moulds, and driven so that the stream of molten metal is delivered into the mould and cannot flow on to their edges. Tapping devices are also arranged to knock the bottom of the overturned mould to free the pig.

* *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xvi. pp. 190-230.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. p. 466.

‡ *Iron and Coal Trades Review*, vol. lxii. pp. 290-291.

§ *American Manufacturer*, vol. lxvii. pp. 449-451; *Iron Trade Review*, December 13, 1900, pp. 13-15; *Engineering and Mining Journal*, vol. lxxi. pp. 7-8; *Stahl und Eisen*, vol. xxi. p. 163-165.

A photographic illustration * has appeared of the Hartman pig iron casting machine, of which one is stated to be in use at one of the Lehigh Valley furnaces. Wrought iron or steel moulds are carried by rock shafts on the outside of a horizontal rotary table driven through clutch gear, which slips in case there is a block. The moulds are placed longitudinally, so as not to be cut by the molten iron flowing into one place. As they pass round they are subjected to a water jet on the underside, and later on from above also, in addition to which they pass through two water troughs, in which the water is maintained at two levels. In the first the bottom of the trough only is wetted, and in the second the water is over the top of the mould. While the mould is in this section a workman loosens the pig, so that the water can get all round it. After leaving this trough the mould is turned over to discharge the pig and to drain off the water. The heat in the mould dries it, and then it is turned up again, and dusted with a powdered bituminous coal. The pigs fall into a conveyor, which leads them through a straight water trough to thoroughly cool them, and then the conveyor lifts them and discharges them into the railway waggons. At starting the moulds are greased to prevent the water adhering, but as soon as they get warm this is not necessary. An iron notch is used at the blast-furnace as the easiest way of controlling the flow, and a blowpipe attachment is fitted in case it chills up, or to open it. A plumbago nozzle is used at the end of the runner or on the ladle, in order to keep the stream of molten iron as uniform as possible.

E. Belani † discusses the methods for collection of the pig iron from blast-furnaces. Attempts, he observes, have been made to entirely replace the hand labour of the pig bed by the use of specially designed mechanical appliances. So far as the author knows, these appliances are all arranged on the same principle—they cause moulds to pass under the outflowing stream of molten iron, whether from a ladle or direct from the furnace. One kind consists of an endless chain, another adopts a revolving disc, a third even pulls the whole heavy pig bed arrangement backwards and forwards in front of the furnace. The author points out that the question arises whether these various constructors really form the desired means, and whether some simpler way is not likely to be more efficacious. It is certainly not necessary to assume that all the work done by the numerous hands now employed should be done by one or two engineers aided by

* *Iron Age*, November 1, 1900, pp. 7–8.
† *Stahl und Eisen*, vol. xxi. pp. 49–50.

mechanical appliances. Mechanism cannot replace hand labour in the tapping of a blast-furnace, with any degree of certainty. This is an operation that requires much care and attention, and is not one that could be lightly handed over to a mechanical device. Looking next at the pig bed itself, it will be seen that the most costly part of this work consists in the removal of the hot pigs. If, therefore, a mechanical device could be used, it would be for this part of the work only. For this neither rotating nor travelling constructions are necessary. A fixed pig iron bed, with tipping rows of mould filled in the usual way from channels, is all that is needed, provided there is also a system of pig iron waggons beneath the moulds to receive and remove the pigs. Such an arrangement as this, he considers, is the one most likely to be satisfactory. He describes how such an arrangement could be made. The iron flowing from the blast-furnace would run, as is customary, into a main channel, and from this into cross-channels. From this point onward the author modifies the method on the lines sketched out above.

The Utilisation of Blast-Furnace Gas.—H. A. Humphrey * discusses the use of power gas and large gas-engines for central stations, and the appendices to the paper contain the results of a large number of tests made with different engines under various conditions. Amongst these are tests of a 400 horse-power gas-engine run with Mond gas. The tests made at Seraing and elsewhere on the Continent are also given in detail.

W. Dixon † shows that the questions of 1896, as to whether blast-furnace gas is rich, clean, and abundant enough, and whether there are suitable engines on the market for the consumption of the gas, have now been amply answered in the affirmative; but he expresses surprise that more has not been done in their practical adoption in this country.

A. Wilson ‡ describes and illustrates a number of gas-engines used with producer and blast-furnace gas.

J. W. Richards § traces briefly the history of the use of blast-furnace gas for the production of power by means of the gas-engine, and then makes a number of calculations as to the saving that may be effected. Three furnaces are considered. The first makes a poor

* *Institution of Mechanical Engineers' Proceedings*, 1901, pp. 41–247.

† *Journal of the West of Scotland Iron and Steel Institute*, vol. viii. pp. 44–48, 115–121.

‡ *Ibid.*, pp. 135–156.

§ *Journal of the Franklin Institute*, vol. cl. pp. 415–430.

gas, with low fuel consumption and with high blast pressure and temperature. Under these conditions the saving works out to about 10 horse-power per ton of pig iron made. With the other two examples these figures work out to over 40 and over 70 horse-power. The first case is that of the ordinary practice of the present day, except that the stove efficiency has been taken at a very low figure. The results of the calculations are fully given in tabular form, and are applied to American practice.

Bryan Donkin * gives a general review of the utilisation of blast-furnace gas in the gas-engine. Amongst other details it is pointed out that the high efficiency attained with the use of poor gas is partly due to the high compression which cannot be employed with richer gas owing to premature ignition. The different solutions of the dust question are briefly summarised; and as regards the application of the power, it is pointed out that the slower speed of large engines enables them to be coupled direct to the blowing cylinders.

F. W. Gordon † gives some calculations on the heat and power available from the waste gases of blast-furnaces, and describes a blowing engine. The figures, derived from the working of one of the South Chicago furnaces, given by himself in a paper to this Institute ‡ in 1886, are recalculated into British thermal units, and used. The consumption then was 1862 lbs. of coke per ton of iron, and the amount is about the same at the present time. The gas contains 26·08 per cent. of carbonic oxide, and there are 6·3 lbs. of gas per lb. of fuel burnt. The total heat in the products of consumption of these gases is 7889 British thermal units, of which 1237 are lost in the chimney gases, and the remainder, less 10 per cent. for radiation, that is, 5976 units, are available. For heating the 4·61 lbs. of blast to 1375° F., 1341 units are required; for compressing the blast to 12 lbs. above the atmosphere, 821 units; for hoisting material, 15 units; for pumping, 43 units; this leaves a balance of 3765 units, or 37 per cent. is utilised in this way. Of the total amount 75 per cent., or 5986 units, are found in the blast and the steam. The author then discusses gas-fired boilers and steam-driven blowing engines, with special attention to the form of the engine used; also giving illustrations of parts of the blowing engines driven by gas-engines.

W. H. Booth § deals with the utilisation of blast-furnace gas in gas-

* *Engineering Magazine*, vol. xx. pp. 422–432.
† *Iron Age*, October 18, 1900, pp. 1-6.
‡ *Journal of the Iron and Steel Institute*, 1886, No. II. p. 779.
§ *Cassier's Magazine*, vol. xix. pp. 341–348.

engines, and discusses its use for the manufacture of calcium carbide and for other purposes.

A paper has been also published by F. Liebetanz,* on the use of blast-furnace gases in the manufacture of calcium carbide.

The engine exhibited by the Cockerill Company at the Paris Exhibition, for use with blast-furnace gas, is described by J. Laffargue.†

Further illustrated accounts of the use of the Oechelhauser gas-engines with blast-furnace gas have appeared.‡

A plan and elevation are given § of the double-acting Koerting two cycle gas-engine, which is built to give 350 brake horse-power.

An illustration of a four cylinder vertical gas-engine of American design is given.||

The Evolution of the Blast-Furnace.—W. Kennedy ¶ describes the progress of the blast-furnace. A small blast-furnace in the province of Hu Peh in China is first illustrated, and a detailed account of the work done with it is given. With its aid the Chinese could make thin castings, 20 inches in diameter, 7 inches deep, and not over 1-16th of an inch in thickness. The Curtin furnace in the United States, with its log-washer for ore, is then taken as an example of the practice at the beginning of the century, when the charcoal industry employed so many hands. Next a furnace at Greenborough in North Carolina is illustrated as an example of the middle of the century, and representing practice as it was until quite recently. Then reference is made to the modern improvements in the charging and the methods of taking off the gas, and the substitution of machinery for hand labour generally. A modern furnace will produce about six tons of iron for each man employed instead of a ton per man in the middle of the century, or one ton for four men at the beginning, or one ton per hundred men in the Chinese furnace.

J. Birkinbine ** briefly reviews the progress of the last half century of blast-furnace progress in the United States.

* *Glückauf*, vol. xxxvi. p. 254.
† *La Nature*, 1900, p. 161.
‡ *Iron and Coal Trades Review*, vol. lxi. pp. 1269–1271.
§ *Engineer*, vol. xci. pp. 23–24.
|| *Engineering and Mining Journal*, vol. lxxi. p. 177.
¶ *American Manufacturer*, vol. lxviii. pp. 1–5.
** *Age of Steel*, January 5, 1901, pp. 66–67; *Iron and Coal Trades Review*, vol. lxii. p. 188.

A New Belgian Blast-Furnace.—J. Smeysters * gives a descriptive account of the new blast-furnace erected by the Marcinelle et Couillet Company. The height of the furnace is upwards of 74 feet, while the diameter of the bosh is about 22 feet. The charging will be performed by self-tipping cars running up an inclined track, this part of the equipment being of American manufacture and design. The furnace-throat is closed by a cup and cone. The particulars of the blowing engine are also given.

In erecting the new blast-furnace at Couillet the character of the coke obtainable in Belgium had to be taken into consideration, and also the variable nature of the ores to be smelted.† It was further considered that any abrupt changes in the internal profile of the furnace must lead to an irregular sinking of the charge, and also that it would be of advantage to have as large a reducing zone as possible. The internal capacity is nearly 21,000 cubic feet. The width at the boshes is about 22 feet 2 inches, and at the hearth 11 feet 5 inches. In order to avoid any ill effect from the bosh angle, a cylindrical portion 3 feet 3 inches in height is inserted between the boshes and the shaft. The firebricks used at the tuyere level contain 43 per cent. of alumina, and those at the boshes 36 per cent. Details as to the furnace construction are given. The boshes and the crucible portion are built up independently of the shaft. The throat is closed by two superimposed Parry cones, which are moved the one after the other by steam power when the furnace is charged. The upper cone has a diameter of 5 feet 9 inches, the lower one a diameter of 9 feet 10 inches. The upper cone carries a sheet-iron funnel, through which the furnace is charged in such a manner as to cause the material to spread out evenly in the lower cup. There are two side take-offs for the gas. These are provided with dust catchers. The other portions of the blast-furnace plant are also described. The blowing engines can give a pressure up to about 2¾ inches of mercury. Each of the two blast-furnaces is provided with four Cowper hot-blast stoves, each of which is about 85 feet high, and about 22 feet wide. The slag is granulated as it runs from the furnace. Special arrangements are made for the tapping of the pig iron. The normal daily outturn per furnace will be 160 to 170 tons.

French Blast-Furnaces.—The Pont-à-Mousson Company possesses blast-furnaces at Pont-à-Mousson, and smelts minette ores.‡ It

* *Revue Universelle des Mines*, vol. lii. pp. 196–201.
† *Stahl und Eisen*, vol. xxi. pp. 1–4, with six illustrations.
‡ *Ibid.*, vol. xx. p. 1262.

possesses large iron ore deposits in the Nancy and Briey ore fields. One of its mines at Marbache raised 131,000 tons of ore in 1899, another mine yielded 23,000 tons, and a third 55,000. All these are in the Nancy field. In the Briey field, although the ore deposits are very large, difficulties of dealing with the water encountered have largely interfered with mining operations. A shaft is to be sunk by means of the Poetsch freezing method, and a daily outturn of 2000 tons is expected. The company possesses five blast-furnaces. These are provided with Cowper stoves almost 100 feet in height. The daily furnace yield is between 250 and 300 tons. The furnaces have closed throats with central take-off. They are driven at present by five steam blowing engines, but the use of blast-furnace gas for this purpose is contemplated.

This work possesses five blast-furnaces, of which the first was put in operation in 1878. A sixth is in course of construction. The company owns iron ore mines containing over 150,000,000 tons of ore, of which the following are analyses:—

	Calcareous Ore.	Red Ore.	Grey Ore.
	Per Cent.	Per Cent.	Per Cent.
Silica	10·70	13·60	15·40
Lime	17·50	7·40	5·20
Alumina	6·00	6·90	6·05
Magnesia	0·85	0·70	0·90
Phosphoric acid	1·46	1·72	1·34
Sulphuric acid	0·12	0·08	0·04
Ferric oxide	41·69	55·69	58·90
Manganese oxide	0·28	0·43	0·34
Loss on ignition	21·40	13·48	11·83
Metallic iron	29·20	39·00	41·25
Metallic manganese	0·20	0·37	0·24

The basic pig iron blown from this contains:—

	I.	II.
	Per Cent.	Per Cent.
Manganese	1·70	1·90
Phosphorus	1·90	1·90
Carbon	2·95	2·85
Silicon	0·80	0·50
Sulphur	0·045	0·04

The dimensions of the blast-furnaces are given. Their daily productions of basic pig iron are respectively 130, 90, 145, and 160 tons.

This latter furnace was only erected in 1898. It is 85 feet 4 inches high, 12 feet 4 inches wide at the tuyeres, 22 feet 2 inches at the boshes, and 18 feet at the throat. It is provided with four Cowper stoves, each 88 feet 7 inches high and 23 feet wide. The blowing engines are capable of delivering to this furnace nearly 50,000 cubic feet of blast per minute. When furnace No. 2 has been rebuilt, and No. 6 furnace completed, the blast-furnace plant is expected to yield about 870 tons of pig iron per day.

Hungarian Blast-Furnaces.—A. Edvi-Illés * describes a number of Hungarian blast-furnace plants. The older methods in use for the direct reduction of iron are first referred to. The first blast-furnace making pig iron was erected at Dobsina in 1680. The subsequent progress of the blast-furnace industry of Hungary is then traced, and statistical details with regard to the production are given. Among the blast-furnace plants of which details are given are those of Count G. Andrassy at Bétler in Gömör County. This has seven charcoal blast-furnaces in operation. In 1898 these produced 34,500 tons of pig iron. At the Concordia Works at Csetnell, in the same county, is a charcoal blast-furnace which makes 4000 tons of white pig iron yearly. Another belonging to the same company at Henczko is served with charcoal mixed with 6 per cent. of coke. In 1898 it consumed 6700 tons of calcined spathic ore, 1700 tons of spathic carbonate, 8700 tons of limestone, 3750 of charcoal, and 140 tons of coke. Hot blast is used. About 3200 to 4000 tons of pig iron are made annually. At Kun-Taplócza this company possesses a third blast-furnace. This too is served with charcoal mixed with a little coke. In 1898 it smelted 7600 tons of raw ore, of which 15 per cent. was spathic carbonate and the rest limonite. The limestone used was 1870 tons and the charcoal 3100 tons. It produces about 3500 tons of grey pig iron per year. A large number of other works are also briefly referred to.

Charcoal Blast-Furnaces in Moravia.—J. Lowag † observes that there is no historical evidence as to the commencement of the iron industry in the neighbourhood of Römerstadt in Moravia, nor indeed in Northern Moravia and Austrian Silesia generally; and no one knows with any certainty who were the first miners there, what their nationality, or whence they came. The belief of some writers

* "L'Industrie des Mines de Fer et Hauts Fourneaux de Hongrie," Budapest, 1900.
† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlix. pp. 129-133.

that Römerstadt was founded in connection with the Roman legions in war with the Markomanni and Quaden is a mere assumption. The oldest known statement as to the place dates from 1350, and here the name is given as Raymerstadt. The author thinks that it was rather the original inhabitants than the Romans who first began mining in these districts. The remains prove that mining and smelting must have existed here in very ancient times. The author sketches the iron production of Römerstadt in historical times. Pessina states in his history of Moravia, published in 1677, that in the Moravian Mountains there was a good deal of iron ore, and that ironworks existed at many places, the most important being the Janowitz Works (Römerstadt), which, with the Pernstein and Hochwald furnaces, produced the best kinds of iron, and from which cannon, balls, muskets, &c., were made. The first blast-furnace was erected at Janowitz in 1760, two others being erected in the following year at Friedrichsdorf and Karlsdorf. The Friedrichsdorf furnace was put out of blast in 1788 on account of an inadeqnate supply of charcoal. The author traces the progress of the Janowitz Works from that time on, showing what was its annual outturn, and how the various furnaces, &c., were increased in number. In 1850 the ore charge for the blast-furnace contained 34 per cent. of iron; from 240 to 250 cubic feet of charcoal were required for each ton of pig iron, and from 300 to 500 lbs. of limestone were added per ton to the ore charge. About this period the want of an adequate supply of charcoal began to make itself felt. When the sixties were reached, the production began steadily to diminish, and gradually, from one cause and another, one charcoal furnace after another had to stop working (the Janowitz Works among the rest), until none remained in this district.

Large quantities of iron ore still remain available. Those of the Janowitz district are magnetites and red hæmatites, brown iron ore being also met with. The former iron ore mining dealt chiefly with two beds separated from each other by some 220 yards of chlorite schist. The ore zone is about 0·63 miles in width and about 6·3 miles long. The beds vary in thickness from a yard to a couple of fathoms, and the iron contents from 30 to 60 per cent. If magnetite and red hæmatite occur together in the same bed of ore, by no means a rare occurrence, then usually the hæmatite is at the roof and the magnetite on the foot wall. At the Bräunelstein mine the ore averages 62 per cent. of iron. The most important of the former mines are named

by the author and briefly described. He refers to some eight of these in all, the beds of ore worked varying from one to six yards in thickness, and the ore contents from 30 to 62 per cent. of iron. At the time iron smelting stopped the ore reserves were estimated at about 16,000,000 tons. Means of communication are good, as, in addition to good roads, a railway station is less than two miles away, and the author thinks that a coke blast-furnace plant would now prove a profitable concern if established at this point, the cost of transport of the coke being more than counterbalanced by the quantity of ore in the vicinity, and the cheap rate at which it could be mined and delivered at the works.

Charcoal Blast-Furnaces in Bosnia-Herzegovina.—According to F. Poech,* one blast-furnace still remains at Stari Majdau, in the north-west of Bosnia. The new Vares Works, situated at the foot of the incline bringing down the ore, includes numerous kilns for roasting spathic and brown ores, two blast-furnaces with five Cowper stoves, and a foundry for pipes and other castings. The new blast-furnace, which is probably the largest charcoal furnace in Europe, is 53 feet high, 15 feet wide in the boshes, and 8 feet in the hearth, with six $4\frac{1}{2}$-inch tuyeres, with blast at 5 lbs. pressure heated to 700° to 800° C. The charge is 190 lbs. ore, 15 lbs. limestone, and 85 lbs. charcoal per 100 lbs. pig metal, and the make from 80 tons to 100 tons per day, the composition varying within the following limits:—

	White.	Grey.
Silicon	0·4 – 0·8	1·8 – 3·55
Manganese	3·5 – 6·0	0·9 – 2·20
Sulphur	0·04 – 0·055	0·04
Phosphorus	0·10 – 0·25	0·20
Copper	0·10 – 0·20	0·07

The total production of the year is 40,000 tons, about three-quarters being white and one quarter grey metal. Lately a cargo of this iron has been sent to Rotterdam.

Blast-Furnaces in Elba.—In January 1900 the first stone of the Elba blast-furnaces was laid at Portoferraio. The two furnaces will be ready for use in a year's time. The gases will be used as motive power in four gas-engines now being made by the Cockerill Company of Seraing. Of these, the one designed to drive the blowing engines will be of 600 horse-power, and the others of 200 horse-power each.†

* "L'Industrie Minérale de Bosnie-Herzégovine," Vienna, 1900.
† *Rassegna Mineraria*, vol. vi. p. 280.

New Russian Blast-Furnace Plant.—M. Pierronne * publishes two illustrations of a new blast-furnace plant at Kertsch, on the Sea of Azov. There is one blast-furnace rather over 81 feet high, 19 feet 6 inches wide at the boshes, and with a capacity of about 18,625 cubic feet. It is provided with twelve tuyeres. This furnace is to smelt the neighbouring iron ores, which contain about 38 per cent. of iron. It will make about 150 tons of foundry pig iron daily.

Another new blast-furnace has been erected at the Alexander Works of the Briansk Smelting Company at Ekaterinoslav. This furnace is about 6·5 feet higher than the one mentioned above, but is of the same width at the boshes. It also has 12 tuyeres. It smelts iron ores from the Krivoi Rog, with an average iron content of 58 per cent. On the fourth day after it was blown in last autumn it made 150 tons of pig iron. It is hoped to raise this to 300 tons. The author states that these are the two largest blast-furnaces in Russia.

New American Blast-Furnaces.—A. C. Johnston † describes in considerable detail, and with the aid of numerous sections, the construction of a modern blast-furnace and its equipment for making 600 tons in twenty-four hours. The Lorrain plant is taken as the example. It consists of two stacks, built in 1899, each 100 feet high, 22 feet in diameter at the boshes, and 14 feet in the hearth. The hearth jacket is carried much deeper than usual, and there are two rings of bronze cooling plates below the tuyeres, ten rings above them, and then a further three rings of cast iron cooling plates, or 277 bronze and 48 cast iron plates in all. The stock lines are protected by twelve rings of cast iron segments built into the brickwork. The furnace is blown through sixteen 6-inch tuyeres. Gas is led through two downcomers, 63 inches in internal diameter, into a dust catcher, and may be further purified in washers. Each furnace has four stoves, the heating surface in each being 34,000 square feet, and two blowing engines with a fifth in reserve. These engines have steam cylinders 44 and 84 inches, and air cylinder 84 inches in diameter, with a common stroke of 44 inches. The air may be delivered at 30 lbs. pressure, but the usual blast pressure is 14 lbs. The stock bins are placed underground, and the material is taken from them to the skip by five trucks with automatic weighing appliances. The skip is counterbalanced and has a capacity of 240 cubic feet, and runs on an

* *Stahl und Eisen*, vol. xxi. pp. 165-166 ; two illustrations.

† *Journal of the Association of Engineering Societies*, January 1901 ; *Engineering News*, vol. xlv. pp. 248-249.

inclined skipway. Steam is supplied by twenty-four vertical water-tube boilers of 250 horse-power each.

An endless belt pig casting machine is in use, and to prevent the pigs sticking the moulds are smoked instead of being washed with clay. Ladle trucks, holding 15 tons, take the iron from the furnaces to the casting machine. The slag ladles hold 200 cubic feet and have renewable cast iron linings. Each furnace is tapped six times daily, and a pneumatic tapping gun is used to stop the taphole. A tilting mixer holding 300 tons receives metal for the steelworks. One furnace ran for a year and the other for about eleven months before being put out of blast, and the production was 162,687 and 132,290 tons respectively, and sections are given to show the lines of the furnaces before and after the run. It was then found that the cast iron rings at the stock lines were of doubtful value, the cooling system in the hearth was soon rendered ineffective by the stopping of the pipes, and a good many breakages at the stoves had to be remedied by heavier sections made of steel. A very large number of sections and plans are given of the different parts. These include plans and elevations of the plant, sections of the furnaces, cooling appliances, valves, gas washer and dust catcher, of the stoves and their valves, burners and chimneys, sections of the charging bins, the furnace top, slag and metal ladles, &c.

C. Larsen * describes the new blast-furnace erected by J. Kennedy at Neville Island, six miles from Pittsburg, for the American Steel and Wire Company, and gives a number of photographic illustrations showing the progress of construction. The furnace is 100 feet high, with 23-foot boshes, and has four blast stoves 100 by 21 feet. Special unloading arrangements are provided for the ore railway waggons and for loading the trucks used for charging; of them a short description is given.

At Phillipsburg, New Jersey, an anthracite furnace, 75 feet high, with a 16-foot bosh, 9½-foot hearth, and 12-foot stock line, was blown out after a run of five years, during which it made 197,162 tons of pig iron from ore containing 57 per cent. of iron. It had fifty-two bronze bosh plates, of which only one had to be renewed, and it was blown through seven 5-inch tuyeres.†

It is stated ‡ that two 300-ton charcoal blast-furnaces are to be built at Saulte Ste Marie, Ontario. Michipicoten ore is to be smelted. Another charcoal furnace capable of making 150 to 175 tons daily is to be built at Marquette.

* *American Manufacturer*, vol. lxviii. pp. 257-260.
† *Iron Trade Review*, January 10, 1901, p. 19.
‡ *Engineering and Mining Journal*, vol. lxxi. p. 249.

II.—*CHEMICAL COMPOSITION OF PIG IRON.*

Irregular Distribution of Sulphur in Pig Iron.—R. Bolling* describes some experiments for ascertaining the distribution of sulphur in cast iron. One-pound samples were taken at intervals from the runner while a cast was being made, and 10 lbs. of the metal thus collected was run into a sand mould about a foot long. After cooling, eight holes were drilled transversely at intervals of 1⅝ inch. Commencing at the top of the bar and taken successively, the borings showed the following percentages of sulphur respectively:—0·036, 0·036, 0·036, 0·036, 0·036, 0·032, 0·030, 0·023. It will be seen that the difference between the two extremes amounts to 0·013. Hence, to obtain a true assay for sulphur, the bar should be drilled through from top to bottom and the drillings well mixed.

Russian Charcoal Pig Iron.—Neumark † gives some analyses of charcoal pig iron and blast-furnace slags from the Ural district. These show:—

Pig Iron.	Per Cent.
Silicon	0·67 to 1·00
Manganese	0·36 ,, 2·16
Phosphorus	0·04 ,, 0·40
Sulphur	Trace ,, 0·07
Copper	,, ,, 0·08
Graphite	,, ,, 3·77
Combined carbon	,, ,, 1·45
Total carbon	0·76 ,, 4·96

An analysis of a ferro-silicon showed 18·1 per cent. of silicon, 0·72 of manganese, 0·11 of copper, and 0·76 of total carbon.

The following are the analyses of slags:—

From	Fe.	Mn.	SiO_2.	Al_2O_3.	CaO.	MgO.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Foundry pig iron	0·2	2·9	52·0	17·0	22·0	5·5
Ferro-chrome	1·0	0·4	45·7	19·1	21·8	9.9
Ferro-manganese	1·0	14·0	33·1	9·2	28·7	6·3
Ferro-silicon	0·5	0·2	42·5	12·8	43·5	0·8
Foundry pig iron	4·5	1·5	46·5	14·0	24·8	4·9
Not described	0·2	3·5	52·2	19·5	10·5	10·7
Open-hearth pig iron	0·5	4·7	44·6	10·7	22·4	16·3

* *Journal of the American Chemical Society*, vol. xxii. pp. 798–799.

† *Stahl und Eisen*, vol. xxi. p. 112.

The fifth and sixth were from the Perm government, the first from the government of Orenburg. The slag from ferro-chrome also contains 0·5 per cent. of chromium.

III.—*BLAST-FURNACE SLAG.*

Slag Cement.—W. K. Hatt * gives a general account of the nature and properties of slag cement, with tables of chemical analyses and mechanical tests of cements from various sources, and also an account of the development of the industry. In America there are six mills making slag cement, and two others which use slag sand as a constituent in cement manufacture. The full results of some tests made at Purdue University in 1900 with four brands are especially dealt with. Those cements containing sulphides are liable to deterioration owing to the oxidation of that constituent.

C. Steffens † describes the results obtained in the manufacture of Portland cement from blast-furnace slag at the slag cement works connected with the Hirzenhain and Lollar ironworks. The method of manufacture is stated to be simple, safe, and certain, and the results obtained, with all the apparatus used, and especially with the rotating ovens, to be in every way satisfactory. The raw material consists of hard limestone and wet granulated slag sand. On account of its chemical properties ground slag is not capable of utilisation. The limestone and the slag have to be dried, and then ground up together and intimately mixed. It is well known how difficult it used to be to dry slag thoroughly, and those works which were not supplied with rotating furnaces found this drying operation a very costly one. Indeed at one such works the drying of the slag cost as much as the burning of the cement itself. By the use of the rotating furnaces the operation becomes very simple and cheap. The slag is mixed with the right quantity of crushed limestone, and is first charged into a calciner heated by the waste gases from the rotating cement furnace. It gets dried in this, and the rotation of the furnace, with the addition of the lime as well, causes the slag to become very finely powdered, even in this drying oven itself. Most of the limestone is at the same time burnt to oxide, and the texture of the whole so greatly changed

* Paper read before the Indiana Engineering Society, February 15, 1901; *Engineering News*, vol. xlv. pp. 164–165.

† *Stahl und Eisen*, vol. xx. pp. 1170–1171.

that subsequent pulverisation is an operation very easy to perform. The result is that this drying "calciner" takes a place as a grinder in the grinding operations. No special firing being necessary, the drying operation not only costs very little to perform, but at the same time yields a product already finely ground, thoroughly dry, and intimately mixed. The subsequent grinding requires, therefore, but little power, and with a maximum output yields a very finely divided material. The powdered material thus obtained is then charged into the rotating cement burner. Works using other types of cement furnaces have first to again moisten the material, add binding materials, press into bricks, and heat, before finally burning it. The whole of these operations are eliminated by the use of the rotating furnace. At the Lollar Works such a furnace yields about 150 casks a day, or almost 50,000 a year. Coal-dust firing is employed. The total quantity of coal used is about 18 to 20 per cent. of the weight of the "burnt clinker." This "clinker" leaves the furnace at a white heat. This is again an advantage, as some cements gain in quality by being rapidly cooled by water, and the large reserve of heat remaining in this hot mass could also be utilised for drying purposes. The "clinker" produced in this way in the rotating furnace is not nearly so solid and compact as that which results when briquetting has first been adopted. The cement produced is of excellent quality. The author thinks that this method will be very widely adopted in the future, being, as it is, both the simplest and cheapest.

Slags from Luxemburg Pig Irons.—Some analyses of slags are published by the Luxemburg-Lorraine Iron Syndicate,* whose production of pig iron in 1899 was 1,712,000 tons. All these slags are from pig irons made from Luxemburg ores. A No. III. foundry pig iron, containing 2·71 per cent. of silicon, yielded a slag whose analysis was as follows :—

SiO_2	Al_2O_3	CaO	FeO	MnO	S.	MgO
32·40	17·16	45·80	1·84	0·20	0·98	2·50

The slag from a foundry pig iron, which contained as much as 6·37 per cent. of silicon, had the following composition :—

SiO_2	Al_2O_3	CaO	FeO	MnO	S.	MgO
34·70	18·70	42·85	0·47	0·12	0·74	2·63

* *Stahl und Eisen*, vol. xx. pp. 1266–1267.

Slags from pig iron intended for steel manufacture contained :—

	I.	II.
	Per Cent.	
Silica	31·10	30·58
Alumina	17·20	17·20
Lime	45·78	45·79
Ferrous oxide	1·52	1·14
Manganous oxide	0·35	0·36
Sulphur	1·10	1·24
Magnesia	2·45	2·56

The Use of Slag.—A. D. Elbers * again advocates the use of blast-furnace slag as a liming material on certain varieties of land. For this purpose it must be thoroughly disintegrated.

G. Lunge † shows that a given granulated basic blast-furnace slag differs from slag from the same source slowly cooled, in that the former contains but very little free silicic acid and a fairly large amount of aluminium silicate, whilst in the latter the proportions are reversed.

IV.—*FOUNDRY PRACTICE.*

Foundry Appliances.—W. P. Pressinger ‡ gives an illustrated description of those foundry appliances which are driven by compressed air. These include the direct acting and other types of pneumatic hoists and cranes, the pneumatic chipping-tool, the air-driven drill, the reversible pneumatic rammer, sand blast by itself and in connection with the tumbling barrel for cleaning castings, air-driven sand-sifters, pneumatic moulding machines, and pneumatic spray producers for painting. The choice of air-compressors is also dealt with.

Illustrations are given § of a pneumatic rammer for sand moulding. It is double ended, and is mounted on trunnions so as to be reversible, and the valve arrangements are such that the length of the stroke may be varied.

F. R. Jones || gives the result of a number of tests of electrically driven machines in machine-shops and foundries. These include cranes, fans, &c.

* *American Manufacturer*, vol. lxviii. p. 12.
† *Zeitschrift für angewandte Chemie*, 1900, pp. 409–412.
‡ *Journal of the American Foundrymen's Association*, vol. ix. pp. 97–112.
§ *American Manufacturer*, vol. lxvii. pp. 454–455.
|| Paper read before the American Society of Mechanical Engineers.

An illustration is given * of an electrically driven machine used by the Lorrain Foundry Company for stripping core barrels from ingot moulds. The pressure is applied by a screw which can be driven at two different speeds from the electromotor.

P. Longmuir † gives a survey of modern foundry practice in iron, steel, and other metals, generally reviewing the points on which advance has been, or is to be made, and giving a number of illustrations of modern appliances. Amongst these are a portable stove and fan for drying large moulds on the floor, and travelling tables for taking the flasks from moulding machines past the cupola for pouring to the point where they are cooled sufficiently for shaking out.

Cupola Practice.—T. D. West ‡ gives some notes on the construction and management of cupolas. For larger cupolas, centre blast is preferred to contracting the cupola at the tuyere level. The increase of height to as much as 30 feet to the charging doors has produced much economy, and even for short runs the height should be 3½ times the diameter. An ample stack should be placed above the charging point. The tuyeres should be at least sufficiently high above the drop bottoms to hold the amount of metal desired, but the height may be decreased if the cupola is tapped at frequent intervals. The slag should be thin. The combined area of the tuyeres should be 25 per cent. of the average sectional area of the cupola, and tuyeres are advantageously placed at a second or upper level to supply air for complete combustion. From 30,000 to 35,000 cubic feet or 1¼ ton of air are required to melt a ton of iron.

W. Sangster § shows that the horse-power required to produce blast for a cupola is equal to three-tenths of the tons melted per hour, multiplied by the blast pressure in ounces per square inch. For forge blast, an allowance of 0·75 horse-power may be made for each forge, and 0·44 horse-power for exhausting smoke.

D. T. Randall ‖ describes the course of instruction in foundry practice at the Illinois University. Some illustrations of the plant are given.

An account has appeared of an experiment made by W. A. Granger ¶

* *Iron and Coal Trades Review*, vol. lxii. p. 442.

† *Engineering Magazine*, vol. xx. pp. 641–664.

‡ Paper read before the New England Foundrymen's Association; *Iron Trade Review*, March 21, 1901, p. 12.

§ Paper read before the American Society of Mechanical Engineers.

‖ *Iron Trade Review*, April 4, 1091, pp. 26–28.

¶ *Engineering*, vol. lxx. pp. 606.

to show the value of using the *evasée* or tapering outlet or discharge pipe for blowing-fans. The blast from a Sturtevant fan driven by a small gas-engine was led first through a straight pipe and then through a tapering pipe into a box from which it had a free outlet. With the tapering pipe much larger quantities of air were delivered.

Machine Moulding.—I. L. M'Cord * compares stripping plate and power ramming machines for moulding, much to the advantage of the former. In machine moulding there are five leading points to be considered: First, getting the pattern and match board together and putting in the sand; second, ramming or compressing the sand; third, removing the pattern from the sand; fourth, placing the mould on the floor; fifth, pouring the iron into the moulds. Other operations, such as preparing the sand, facing the moulds, shaking out the castings, may be taken to be the same for power and for hand moulding. A saving may readily be made in one or more of these operations, but it is difficult not to increase the expense in some of the others at the same time. Some instances are given by the author to show that much more time is often taken in drawing the pattern than in ramming it. In one case the ratio was 38 to 7, but in this case the pattern was admittedly difficult to draw. The economies that have arisen from these power ramming machines are very often to be ascribed to the other improved machinery which is used in connection with them and not to moulding itself; and the author thinks that the hand ramming, stripping plate machine will and does give far better results. Especially is this so when reversible pneumatic rammers are used.

These opinions are strongly controverted by E. H. Mumford † and others. It is pointed out that power ramming, that is, pneumatic pressing machines, use very much less work than the numerous blows given by a workman who uses either hand labour or pneumatic percussive rammers. Further, the author has given a very low estimate for the speed.

An illustration is given ‡ of a large stripping plate moulding machine for castings 6 feet in length and weighing 300 lbs., intended for the side bars of tramway bogie frames.

* Paper read before the Foundrymen's Association, November 7, 1900.
† *Iron Trade Review*, November 22, 1900, p. 15.
‡ *Ibid.*, February 21, 1901, p. 12.

H. Whiting * describes the method of using the Maywood stripping plate for moulding M.C.B. draw-bars at a works at Melrose Park, Illinois, where five sets of one cope and one drag machine each are in use. The flask is lifted on to the stripping plate by an air hoist, the patterns brushed with oil, sand sprinkled in, and then sand is filled in from a shoot, first moulding sand and then floor sand. At present two men ram by hand, but it is intended to use pneumatic rammers. The mould is then stripped by air pressure and removed by the hoist to the floor.

W. D. Forbes † points out the great perfection now attainable in small and finished castings, and thinks that machine work may be much lessened by their use.

Illustrations have appeared ‡ of portable riddling appliances for foundry sand, in which the sieve is shaken by a small pneumatic cylinder.

It often happens in shops that pipe fittings of odd shapes, not likely to be used more than once, are wanted in a great hurry, and it is therefore necessary to minimise as far as possible the time and expense of pattern-making. J. M. Richardson § gives some practical suggestions on the improvising of patterns and core boxes to suit individual shapes of common occurrence, such as bends, offsets, and U-pipes, with illustrations showing the methods he adopts.

R. H. Palmer describes || a method of moulding large castings by bedding in the floor. Illustrations appear of the moulding of a gas-engine bedplate in this manner, and the construction of the mould is fully explained.

R. H. Palmer ¶ describes the method of moulding a gas-engine bed in a three-part mould. The construction and arrangement of the mould are fully gone into.

Defects in Iron Castings.—D. Brown ** describes the various defects in iron castings and discusses their cause. Blowholes are due to damp sand, defective cores, improper venting, and small or incorrectly placed risers or gates. Venting is only too often left entirely to the moulder's judgment. The extraction of cores through

* *Iron Trade Review*, January 3, 1901, pp. 22-24.
† *Cassier's Magazine*, vol. xix. pp. 308-311.
‡ *Iron Age*, February 28, 1901, p. 14.
§ *American Machinist*, vol. xxiii. pp. 1185-1186.
|| *Ibid.*, vol. xxiii. pp. 1162-1163.
¶ *Ibid.*, vol. xxiii. pp. 1182-1183; three illustrations.
** *Transactions of the Liverpool Engineering Society*, vol. xxi. pp. 61-77.

small openings is often only incompletely done or tends to breakage of the casting. The next most common defect is due to the presence of dirt or impurities, especially owing to the washing away or breakage of part of the mould. Badly fitting cores, insufficient heat in the metal, too few or small runners and risers, and shortage of metal are other causes of defects. Feeding of the metal is of importance to prevent hollows. Cracked and twisted castings are due to many causes, amongst which are unsuitability of the metal and bad design, allowing undue cooling strains. Insufficient weighting of the cope is a cause of other accidents and defects.

F. Wüst * discusses faulty castings and their origin. This may lie in the use of unsuitable pig iron or scrap, while two important parts are played in casting by the character of the fuel and limestones used and the way the fusion is effected. The author, however, does not further consider these, but assuming that the fault had not its origin in either of the above causes, and that good hot metal is obtainable, proceeds to consider the further possible sources of error. To begin with, the molten iron runs into the casting ladle. This should always be well coated with a mixture of one-third part clay and two-thirds of "lean" sand, these components being further mixed with about double their volume of horse-dung. When this mass has dried on the ladle, the cracks in the coating are to be carefully filled in and the whole "blackened." The mixture used for this purpose should be more fire-resisting than that employed for other purposes, and should consist of one part by volume of graphite mixed with one-half part of dry clay and one-half part of chamotte or ground crucible. Despite the fact that the first coating on the pan is in this way covered with another that is infusible, it is not possible to avoid, especially in the case of ladles of large capacity, the ladle coating gradually melting away and giving up slag-forming constituents to the iron. In many works, therefore, the larger ladles are lined with thin firebricks, a method which largely diminishes this trouble. Other kinds of mixtures for coating ladles are referred to. The ladle must be well dried before use. When the iron is in the ladle, care must be taken to prevent it from cooling. For this purpose the molten metal is covered with ground coke, sifted charcoal, or sawdust. Allowing the metal to stand in the ladle has a good effect on its character. The absorbed gases can escape, the manganese and silicon present can act on the dissolved ferrous oxide and decompose it, forming manganous silicate which

* *Stahl und Eisen*, vol. xx. pp. 1041–1048 and 1098–1104; 42 illustrations.

passes into the slag, and the dissolved carbon can also act in a similar manner, carbon monoxide being produced, which escapes into the air and burns. The manganese present also has time to assist in the elimination of any sulphur present by the formation of manganese sulphide, which rises to the surface of the bath of metal, and then passes into the slag. The hotter the metal, the more perfect are these reactions. Cold metal does not purify itself in the same way, as it is too thick-fluid. It is necessary that the iron shall be covered with a layer of some material, which will keep off the oxygen of the air, such as those already named, and covering the bath of metal with charcoal, coke, &c., not only keeps the metal hot but prevents oxidation. Additions are frequently made to the metal in the ladle to eliminate dissolved gases and oxides. These can be divided into two general types: (1) those which act mechanically and (2) those which exert a chemical action. To the first class belong such additions as lead, zinc, and tin. These metals are added to the bath in quantities amounting to from ten to twenty grammes per ton of iron. They boil away at the temperature of the bath and so help to bring gases and impurities to the surface. Stirring the metal before pouring has, however, the same effect, and the metals mentioned will not reduce dissolved oxide. To the second group belong aluminium, sodium, and magnesium. Some time ago "ferronatrium" was put on the market, but of late nothing has been heard of it, and the use of magnesium is rare. On the other hand, the addition of aluminium is more general. It is added either as the pure metal or as ferro-aluminium, and in quantities amounting to about 0·02 to 0·05 per cent. of the weight of the iron to which it is added. The aluminium is added in various ways, but the addition is only effective if it is submerged below the surface of the iron by some suitable means. Otherwise a considerable proportion burns away. Aluminium decomposes dissolved oxides even when the metal is relatively cold, the alumina formed passing away into the slag. By the decomposition of the dissolved ferrous oxide the iron becomes more thin-fluid and apparently hotter. It can readily be shown by calculation that this cannot be due to the combustion of the aluminium, as the quantity of this which is added is far too small to exert any influence by its combustion on the large quantity of iron to which it is added.

When the iron is about to be poured the surface is scraped clean, some dry moulding sand being thrown on the clean surface of the metal. This produces a thin-fluid coherent slag, which protects the iron from

further oxidation during the casting process, while it is prevented from passing forward with the iron. The author then describes the Poetter divided casting ladle. The further stages of the casting process are then discussed, with the appliances in use and their numerous modifications and casting considered generally. A large number of different shapes of moulds are dealt with.

Large Casting.—An illustration is given of a large casting for a desilvering kettle. Its dimensions are 9 by 15½ feet with a 9-inch flange and it is 4 feet in depth. The thickness is 2 inches and the weight is 21,100 lbs.*

A casting, weighing 110,000 lbs., for the bedplate of a blowing engine was made at Milwaukee. Its over-all measurements are an inch or two under 24 by 10 by 5 feet; 126,000 lbs. of metal were poured in the course of its construction.†

The Manufacture of Cast Iron Pipe.—A series of articles has appeared ‡ on the manufacture of cast iron pipe in the United States. After a brief historical sketch, the present conditions of the trusts controlling the industry are considered. The Camden Works in New Jersey are then described. Here the pipes are cast in 12-foot lengths in cast iron flasks. The flasks are made in two parts hinged together, and are rammed in a vertical position with sand and clay round a pattern. The mould is dried over an oven to which it acts as a chimney. The cores are made on perforated steel pipes wrapped with hayband and coated with clay tempered with sand, and they are dried in ovens. Pipes are cast in a vertical position, sometimes with the flanges up and sometimes down. The casting is removed by opening the flask, and the core is easily withdrawn as the hay has been burnt. Next the dimensions, weights, and standard sizes of pipes are given. The fifth article deals with the annular pit and the longitudinal pit system of casting, and a full description is given of the Anniston plant, which has six annular pits in which pipes 2 to 7 feet in diameter are made, and of the Whiting Company's plant with longitudinal or rectangular pits.

Mending Castings.—E. B. Gilmour § describes the method of

* *Iron Trade Review*, November 1, 1900, p. 11.
† *Iron Age*, November 29, 1900, p. 22.
‡ *Engineer*, vol. xci. pp. 157, 232, 258, 268, 313, 389.
§ *Journal of the American Foundrymen's Association*, vol. ix. pp. 98–99.

burning or mending castings by running on molten iron. Loam moulds are fitted round the defective part, and the casting with the mould attached is placed on a car, and run into an oven where it is heated up to about 600° F., more or less. When ready, enough iron at a good temperature is run through the mould to melt the iron of the casting for about an inch on all sides, and then the work is returned to the oven, where it is allowed to cool slowly. Many castings can be burned at a much lower temperature, or even without the preliminary heating. In mending broken rolls, a loam mould with a hole in the bottom is used, and the iron is run through until the surface is felt to be well melted. Broken castings mended in this way are often stronger than the originals, as the initial strains are relieved.

Specifications for Foundry Materials.—C. Scott * has drawn up a series of specifications which are used by a firm in Wisconsin for the purchase of foundry materials. They include a number of general directions as to the quality desired, and the methods of using the various materials are also indicated. For coke the limits are:—moisture not over 1·5 per cent.; volatile matter not over 3·5; fixed carbon must be over 86; sulphur not over 0·75; ash from 5·5 to 11·5 per cent. Foundry irons are to be as follows:—

	No. 1.	No. 2.	No. 3.
Silicon not less than	2·50	1·95	1·35
Sulphur not exceeding . .	0·03	0·04	0·05
Phosphorus ,, ,, . .	0·60	0·70	0·80
Manganese ,, ,, . .	0·50	0·70	0·90
Carbon usually	3·0 to 4·5	2·9 to 4·2	2·5 to 4·0

Other kinds of iron are:—

	Silicon Pig.	Ferro-Silicon.	Manganese Pig.	Malleable Bessemer Pig.
Silicon	3·0 to 5·5	7 to 12·5	not under 2·5	0·7 to 2·10
Sulphur not exceeding .	0·04	0·04	0·04	0·045
Phosphorus ,, ,, .	0·90	...	0·70	0·15
Manganese not under .	0·30	...	0·90	0·3 to 1·2
Carbon ,, ,, .	2·50	...	...	3·75

* *Iron Age*, November 1, 1900, pp. 10–13.

Charcoal iron and phosphoric pig iron are also specified as follows:—

	Charcoal Iron.	Phosphoric Pig.
Silicon	0·3 to 2·75	not under 1·50
Sulphur not over	0·025	not over 0·055
Phosphorus ,,	0·25	not under 1·0
Manganese ,,	0·70	0·3 to 0·9
Carbon	2·5 to 4·5	not under 3·0

Moulding sand is tested for fineness by treating it on a series of sieves in a particular way, which is described in some detail, but no analyses are specified, though examples of analyses of a suitable character are given for silica or fire sand, moulding sand, and core sand. Finally the kinds of scrap desired are also mentioned. As a guide to the analysts, the methods of analysis are stated.

Some comments on the requirements of the J. I. Case Threshing Machine Company of Racine, Wisconsin, have been published.* It is pointed out that these appear rather of the character of pious wishes than strictly practicable of being carried into effect.

For foundry coke, best 72-hour coke is preferred, with 56 per cent. of pore space and 44 per cent. of coke material. The following are averages of a light and of a heavy coke, the first of which gives quickly an intense heat, the latter a more steady uniform heat.

	I. Per Cent.	II. Per Cent.
Moisture	0·33	0·49
Volatile materials	2·25	1·31
Carbon	90·54	87·46
Sulphur	0·60	0·72
Ash	6·28	10·02
Pore space	52·94	50·04
Coke substance	47·06	49·96
Specific gravity	1·697	1·890
Calories	13,540	12,937

Henning † shows that with a suitable and uniform quality of pig iron good and uniform castings will result if the practice in the cupola is kept at a steady level. But good castings cannot be made if the percentage of metallic iron in the pig iron charged into the cupola falls much below 92, as then the castings become undesirable, porous, and weak. When the percentage is below 89 the castings must be failures.

* *Stahl und Eisen*, vol. xxi. pp. 41–42.

† *Journal of the American Foundrymen's Association*, vol. ix. pp. 121–124.

Analysis in Foundry Work.—R. Buchanan * urges the necessity of chemical analysis in foundry work and materials, and gives instances of its application to iron, coke, sand, limestone, and slag. Some marked differences between buyer's and seller's analyses were found to occur, and in other cases the differences between different qualities have led to changes and corresponding saving.

T. D. West † shows the present irregularities that obtain in grading pig iron by analysis, and proposes ten grades, in which the silicon advances 0·25 and sulphur 0·01 to 0·03 or more in each grade.

G. C. Davis ‡ gives a table to show the use of analyses in making up foundry mixtures.

Saving Iron from Cupola Slag.—C. H. Putnam § passes the slag from the cupola through a tumbling mill with the staves set rather close together. Here it is crushed, and the powdered slag and the finest particles of iron fall out, leaving the coarser iron in the mill. The fine refuse which was formerly thrown away is now passed through a magnetic separator, which is in the form of an inclined rotating cylinder wound with a coil for the magnetising current. The iron remains inside, and the iron-free slag drops out at the lower end. On breaking the current, which is done at intervals, the iron is allowed to fall out also. The crushing need not be so fine in the first instance if the separator is used, thus giving a further economy. The shot iron is then melted in the cupola. By itself it gives a strongly mottled pig, but it can be used mixed with other pig if a sufficient quantity of softener is added. In the discussion, it generally seemed to be considered that the shot recovered was not of great value in the cupola, and that it did not melt properly or give a good yield, besides having a hardening effect.|| The author maintains his position, and thinks that other experimenters may have lost some of the shot through using too high blast pressure.

American Foundries.—C. L. Prince ¶ describes the foundry and plant of the General Electric Company, with the aid of illustrations of the exterior and interior. The total floor space is about 131,000 square feet, and the buildings are well lighted through ribbed and

* *Engineering*, vol. lxxi. pp. 535–538.
† *Journal of the American Foundrymen's Association*, vol. ix. pp. 125–130.
‡ *Ibid.*, vol. ix. p. 63. § *Ibid.*, vol. ix. pp. 101–104.
|| *Iron Trade Review*, December 13 1900, pp. 18–19; December 20, p. 15.
¶ *American Manufacturer*, vol. lxvii. pp. 370–372.

wired glass by day, and by electric light at night. All the cranes are driven by electro-motors, but the ramming is done by pneumatic rammers. There are four cupolas with an hourly capacity of over 40 tons. In the medium-sized core ovens there are no doors, but the ends of the trucks are made to fit the openings of the ovens, and the trucks are moved by pneumatic power. The whole building is warmed and ventilated by two fans, which drive the air over steam-heated coils. Six hundred men are employed, for whom extensive washing arrangements are provided.

A plan and some illustrations are given * of the new foundry at Maywood, Illinois. The largest building is 60 by 150 feet, with a steel truss roof supported on steel posts, and having a lantern roof. All the cranes, rammers, and lifts are worked by compressed air.

* *Iron Age*, November 22, 1900, pp. 16-18.

PRODUCTION OF MALLEABLE IRON.

Puddling.—Lieut.-Colonel L. Cubillo * has investigated the process of puddling with the view of determining whether the oxygen used in oxidising the impurities comes from the fettling or from the air, and in what proportions. For this purpose careful observations were made at all stages of a heat, and analyses are given of the iron and slag at frequent intervals. The charge consisted of 484 lbs. of cold pig iron, and the furnace was coated with 398 lbs. of ore. 407 lbs. of balls were obtained, and 398 lbs. of slag, consisting of 363 lbs. of tap cinder, 50 lbs. of hammer slag, and 3·3 lbs. of slag from the rolls. After charging, the iron was melted in 25 minutes; 14 minutes later the puddler commenced work, and the balls commenced to form after another 28 minutes, the first ball being drawn 8 minutes later, or 75 minutes after charging. Analyses of the pig iron and of the balls showed :—

	C.	Mn.	Si.	P.	S.
Pig iron . . .	2·85	0·540	2·72	0·44	0·16
Balls	0·210	0·005	0·015	0·015	0·008

Analyses of the ore used and of the slags were as follows :—

	From Furnace (Tap Cinder).	Hammer (Hammer Slag).	Rolls (Roll Slag).	Ore.
SiO_2 . . .	13·75	16·98	8·13	11·45
FeO . . .	59·54	56·57	62·36	..
Fe_2O_3 . . .	16·92	15·00	23·14	75·98
Al_2O_3 . . .	...	1·74	0·89	2·89
CaO . . .	4·10	4·65	2·18	1·85
MgO . . .	1·83	1·91	1·25	0·56
S	0·091	0·148	0·097	0·027
P_2O_5 . . .	0·68	0·904	0·352	0·022
MnO . . .	1·16	2·04	1·26	1·03
Fe	58·16	54·50	64·70	...
P	0·297	0·375	0·153	...

* Paper read before the South Staffordshire Iron and Steel Institute.

The loss, weight of cinders, and ore consumed is shown below :—

	Percentage of Impurities.		Total Weight in Kilogrammes.		
	In Pig Iron Charged.	In Balls.	In Pig Iron Charged.	In Balls.	Oxidised in the Operation.
C	2·85	0·240	6·270	0·444	5·826
Mn . . .	0·54	0·005	1·188	0·009	1·179
Si . . .	2·72	0·015	5·984	0·028	5·958
P	0·44	0·015	0·968	0·028	0·940
S	0·16	0·008	0·352	0·015	0·337
			14·762	0·524	14·240

The author, with these data, then proceeds to calculate the weights of oxygen consumed by the iron and its impurities, and finds that of the total 61·728 kilogrammes no less than 57·94 are derived from the coating of the furnace, and this leaves only 3·788 to be supplied by the air. It is therefore considered that the oxidation of extraneous matters is effected by the change of ferric oxide to magnetic oxide.

A graphic diagram is given to show the elimination of the various impurities. Practically all the silicon, manganese, phosphorus, and sulphur are gone within two minutes after fusion, and the remainder disappears slowly. The carbon at that point has slightly increased, and then is more gradually and uniformly oxidised, though the rate increases comparatively towards the end.

Illustrations have appeared * of a puddling or bushelling furnace, and of a heating furnace equipped with a mechanical stoker.

In the discussion † on some notes on boilers by R. D. Munro, reference was made to egg-ended boilers placed on heating furnaces to utilise the waste heat.

A. af Forselles ‡ describes an oil-fired reverberatory furnace designed by H. Krusell. Oil is fed into the top of the combustion chamber and burnt by air preheated by leading it under the furnace. A jet of air is directed on to the bridge to obviate coking at that point.

Manufacture of Best Yorkshire Iron.—F. J. R. Sutcliffe § directs attention to a paper on the "History, Progress, and Description

* *Iron and Coal Trades Review*, vol. lxi. pp. 1055–1056.

† *Journal of the West of Scotland Iron and Steel Institute*, vol. viii. p. 126.

‡ *Teknisk Tidskrift*, 1900, pp. 79–82; *Engineering and Mining Journal*, vol. lxxi. p. 435. See this volume, p. 388.

§ *Bradford Observer*, September 15, 1900.

of the Bowling Ironworks, by Joseph Wilcock," which was read before the Mechanical Science Section of the British Association on the occasion of their visit in 1873. Some of the facts then given are interesting now, and seem to bear on the question which has so often been the subject of discussion, and still remains undecided, viz., which of these firms, Low Moor or Bowling, first made the brand of iron known throughout the world as "best Yorkshire," and therefore were the first to commence operations. The late Mr. Wilcock in the preparation of his paper found books which clearly proved that the first blast-furnace at the Bowling Ironworks was blown in in 1788, while at the sister works at Low Moor the first blast-furnace was not blown in until August 1791, or about three years later. Cudworth, in his "History of Bolton and Bowling," describing the Bowling Works, states that "the boiler plates for the steam boiler put down at the commencement of the Low Moor Works were made at the Bowling Ironworks," which, if correct, is additional evidence that the late world-renowned "Bowling iron" was undoubtedly the first brand of iron known everywhere as "best Yorkshire."

Wrought Iron Works.—The Emlyn Works were built at East Chicago during the first six months of 1900, mostly with second-hand machinery. The main building is of L-shape, with wings 350 and 375 feet long and 120 and 132 feet in width respectively. Scrap is received in the first part, and close to the scrap piles are placed five double puddling furnaces and one reheating furnace for square piles. All these have 250 horse-power vertical water-tube boilers. The puddle train has three sets of 18-inch rolls driven from a 28 by 48-inch engine, which also drives a coffee-mill squeezer. Four reheating furnaces serve the two sets of finishing rolls, and also have vertical boilers attached. The finishing rolls are in the other wing, and comprise a Belgian and a bar train, the latter having a high speed for rolling bar rounds. Overhead trolley tracks are used in part of the mill for transferring the material.*

History of Iron.—Sir Lowthian Bell † shortly reviews the history of iron, and refers to some of his early experiments on the rate at which metalloids are removed in various processes of refining the metal, and also to the height of blast-furnaces.

* *Iron Age*, October 25, 1900, pp. 4–5.
† Address to the Institution of Junior Engineers, December 1900.

The year 1801 was in no way remarkable in connection with the iron trade, and very little is recorded as to its position at that date.* Five years earlier, in 1796, there were 121 blast-furnaces at work in the United Kingdom, 104 being situated in England and Wales and seventeen in Scotland. The average make for the year of those in the former group was 1048 tons each, and of the latter 946 tons, or 20 and 18 tons per week respectively, the total make being 125,079 tons. In 1800 it was 156,000 tons, and in 1806 it had increased to 258,206 tons, made by 173 furnaces, of which number 162 were worked with coke; and the average make had increased to 1640 tons, or nearly 30 tons per week. In ten years, therefore, the capacity of the blast-furnace had been augmented by about 50 per cent.; and as this took place before the use of hot-blast, which was not introduced until about a quarter of a century later, the augmentation must be mainly attributed to the increased blowing power made available by the improvements in blowing-engines and their substitution for bellows. The great Scotch iron industry was also beginning to develop; the Calder Works, with six blast-furnaces, had been started in 1800, at which date blackband ironstone was discovered by David Mushet, although the full value of this discovery was only realised in late years. In France in 1801 the make of pig iron from 530 furnaces blowing was 140,000 tons, of which only a single one was worked with coke. This was at Le Creusot, where it had been introduced by Wilkinson shortly before the outbreak of the French Revolution. The consumption of cast iron for ordnance purposes in the United Kingdom in 1801 was 28,250 tons, or nearly one-fifth of the entire make of the year. In the manufacture of malleable iron the use of the puddling furnace had become pretty general, Cort's patents having run out in 1797 and 1798 respectively. The largest development seems to have been in South Wales, where the Cyfarthfa Works took a prominent place, producing 60 or 70 tons of bar iron per week. This was made from refined metal upon a silica bed, the puddling of grey iron upon an oxide bottom being as yet unheard of. At the same time, charcoal open fires, whether for finery or welding use, were still of considerable importance, and in South Wales, especially in connection with tin-plate making, they lived on for seventy or eighty years more, having only been finally killed by the introduction of the open-hearth process as a method of producing tin bars.

Steel-making by cementation of Swedish iron with charcoal and

* *Engineer*, vol. xci. pp. 22-23.

fusion of the blister steel in crucibles was carried on in Sheffield in much the same manner as at present, having regard to the difference in scale of the operations, the process having been substantially perfected by Huntsman. The state of the steel trade in this country is remarkably well described and illustrated in Broling's work. He visited England in 1797–99, on behalf of the Swedish Board of Ironmasters, with a view of introducing the manufacture into Sweden, and his drawings of the works proposed are remarkably like those in use at the present day.

The year 1800 was noticeable for the first appearance in the records of the Patent Office of one of the principal names in connection with the iron trade, namely, David Mushet, who, on November 13, 1800, patented a method of making cast steel by melting malleable scrap with charcoal, coke, plumbago, coal, and other carbonaceous matters, which must be regarded as the first departure from the method of melting blister steel alone with a siliceous flux as practised by Huntsman. The same patent describes a method of coking in flue ovens by external heat, and the roasting of iron ore simultaneously with the coal to torrefy them for the blast-furnace, an idea which has lately been revived in connection with the utilisation of the small magnetic ore of the Lapland mines. The interesting process of making malleable castings is only a few years younger than the date under review, it having been patented by Samuel Lucas, May 30, 1804.

The foundry cupola is somewhat older than the century, having been patented by Wilkinson in 1794. Broling gives drawings of several patterns in use in his time. One of these is about 20 inches square and 5½ feet high, but others are larger. The largest is about 12½ feet high, with a circular lining and boshes like that of a blast-furnace. Wilkinson's original proposition was to use these for ore smelting, and among the designs is included one with an elongated hearth, very similar in form to that of the Rachette furnace of about half a century later in date. It does not appear, however, that they were ever used in this way, but for foundry purposes they seem to have been pretty generally employed in London at the beginning of the century.

A number of portraits of different men connected with the iron industry during the present century have appeared.*

M. Geitel † gives an historical account of the trade-marks of the

* *Iron and Coal Trades Review*, vol. lxii. pp. 131, 175.
† *Centralblatt der Walzwerke*, January 15, 1901.

German iron and steel industries. Facsimiles are given of a number of ancient marks still more or less in use.

The progress in the metallurgy of iron and steel during the nineteenth century is traced by Bennett H. Brough.* The paper is illustrated by portraits of Josiah Marshal Heath, Sir W. Siemens, S. G. Thomas, the Duke of Devonshire, first President of the Iron and Steel Institute, and Alfred Krupp. There are also illustrations of Black Country blast-furnaces in 1850, of casting open-hearth steel at Krupp's works, and of the Bessemer Gold Medal.

J. M. Swank † gives some details of the early iron enterprises in Cambria, Somerset, Westmoreland, and Indiana counties, Pennsylvania. The Juniata valley and the Johnstown district are especially dealt with, and considerable attention is paid to the question of transport in the early days. The gradual rise of the cast and the wrought iron industries and their manufactures is traced, with numerous references to the firms and factories and other works engaged in the production.

E. W. Hassler ‡ gives a short account of the smaller iron industries in Pittsburg during the last century, giving the credit to a French gunsmith in 1731 as being the first artificer in the metal.

* *Feilden's Magazine*, vol. iv. pp. 42–48.
† *American Manufacturer*, vol. lxvii. pp. 332-334.
‡ *Ibid.*, vol. lxviii. pp. 325, 356, 392.

FORGE AND MILL MACHINERY.

Steel Forgings.—According to H. J. F. Porter,* the Bethlehem Iron Company can make castings up to 300 tons for forgings, but the largest at present made is 125 tons. The steel is cast from ladles, and is compressed in the fluid state by a 7000-ton press to avoid piping and blowholes. The mould is made 50 per cent. larger in diameter than the finished forging, and 10 to 15 per cent. longer than the finished ingôt to allow for compression. All large castings are now bored out in the centre to remove the effects of segregation.

Steam-Hammer Foundations.—In connection with the matter of machinery foundations and vibrations resulting from their insufficiency, there comes to mind the apt remark made by some one concerning a certain steam-hammer, that it seemed to him much like an earthquake on stilts. Steam-hammer foundations have, indeed, proved difficult things to deal with in many instances, owing to the particularly trying conditions involved in the operation of such a piece of apparatus. In erecting the 125-ton steam-hammer of the Bethlehem Steel Company a number of years ago—the largest hammer in the world—a foundation about 60 feet square was prepared, and piles were closely driven over the whole area. The piles were covered over with timber 34 inches square, and on top of these were put steel beams about 35 feet long, and each weighing something like 40 tons. On top of these there was more cross-timbering, and then the anvil block was put on, weighing about 1500 tons. After running the hammer for a short time the foundation went down 8 or 10 inches, and, unfortunately, did not go level, which made matters worse. John Fritz, under whose supervision the work was done, said that he thereupon took out everything down to the piles, levelled the foundation up again, and put in a 2-foot thickness of wood shavings. A lot of men were put on to tramp that down to about 16 or 18 inches;

* *American Manufacturer*, vol. lxviii. p. 110.

the heavy timbers were then placed on the shavings; next came the steel beams, placed crosswise, and on top of these 10-inch square timbers. After these came about 15 cwt. of cast iron, covered with 3-inch plank and 12 inches of cork. On top of the cork there were again 10 inches of timber, and then finally came the anvil block. The elastic shavings bed was intended to absorb the heavy blow on the foundation, and subsequent experience showed that it admirably accomplished its purpose.*

Stripping Ingots.—Further illustrations are given † of the ingot stripper devised by J. Evans and used at Cyfarthfa and at the Cleveland Steelworks. This is a three-ram hydraulic machine designed for stripping two ingots at once, the mould being lifted by the outside rams against the third ram, which is held stationary while the pressure is applied, but is movable otherwise to accommodate various lengths of ingots.

Ingot Cranes.—Illustrations ‡ have appeared of an overhead travelling crane for handling ingots between or in the pits and the rolling-mills. The girder is of the usual box section, and the trolley which runs upon it is provided with a turn-table arrangement on which is the hoisting and rotating part of the machine. This gives great flexibility of movement. The hoisting is accomplished by two drums, and a third drum serves to open and close the tongs.

H. Rieche § considers a number of points relating to travelling crane plants. In all twenty-seven different constructions are illustrated and dealt with. These include, amongst others, safety couplings for the prevention of overloading.

Continuous Rolling Mill Plant for Hoop Iron.—A plan and description are given ‖ of the Union plant at Youngstown, Ohio, for the continuous rolling of hoops and cotton ties. Billets 1½ and 1¾ inch, and weighing 230 to 300 lbs., are charged and withdrawn by roller feeds at opposite sides of a heating furnace, with a bed 30 by 16 feet. As each billet is introduced it pushes the others laterally

* *Cassier's Magazine*, vol. xix. pp. 410-411.
† *Iron and Coal Trades Review*, vol. lxi. pp. 1163-1164. See *Journal of the Iron and Steel Institute*, 1900, No. I., p. 372.
‡ *American Manufacturer*, vol. lxvii. p. 311.
§ *Stahl und Eisen*, vol. xxi. pp. 79-181, 227-230, 285-291; twenty-seven illustrations.
‖ *Iron Age*, November 29, 1900, pp. 8-9.

towards the discharging side. There are two continuous trains. The first or roughing train has six stands, and the finishing train three stands, all being driven by a 24 and 48 by 60 inch compound-condensing engine. The fifth pair of rolls is driven in the opposite direction to the others, so that the work takes an S-shaped path. A flying steam-shear and a special form of pipe-guide is placed between the two sets of rolls. The finishing rolls are driven by belting, and speeded to avoid looping between the rolls. The emerging strip is led through a water trough, and then is laid by a vibrating device in a serpentine form on a travelling belt, on which it cools and assumes the proper blue colour. Then the strip is coiled on automatic reels, and when it is cool enough to handle it is uncoiled, straightened, cut into lengths, and bundled.

Wrought Iron Mill.—A plan is given of the new bar iron plant erected in Cleveland, with six bushelling and two puddling furnaces. There is a 48-inch squeezer, a 20-inch muck bar mill consisting of two three-high trains driven by a 28 by 48 inch Corliss engine, a 12-inch breaking-down mill, and a 10-inch finishing train driven by a 26 by 48 inch engine.*

Rolling Mill Engines.—An illustration and plans are given of the Allis reversing mill engine built for a works in Worcester in the United States. The cylinders are at right angles, one being vertical, and Corliss valve gear is attached.†

A photographic illustration has appeared ‡ of a large right and left hand screw to be used for setting up the edging rolls of a plate mill in the south works of the Illinois Steel Company. It is 23½ inches in diameter, 11-inch pitch, double threaded, and is 17½ feet long over all.

In a presidential address L. D. Thomas § deals with the progress of the iron and steel industries, and advocates rope-driving and quicker speeds in mills.

E. Widekind || describes two rolling-mill plants at Vandergrift, Pennsylvania. The descriptions are accompanied by illustrations of one of the plants.

* *Iron Trade Review*, January 31, 1900, pp. 8-19.
† *Iron Age*, November 29, 1900, pp. 1-3.
‡ *American Machinist*, vol. xxiii. p. 991.
§ *South Staffordshire Iron and Steel Institute*, October 27, 1900.
|| *Stahl und Eisen*, vol. xx. pp. 1048-1050; two illustrations.

Plate Mill.—A general plan of the 48-inch universal plate mill at the Homestead Works is given,* together with photographs of the mill, the heating furnace with its charging and drawing machine, the shear department with inverted castor arrangements for moving the plate, and of the hot beds. The plates are rolled from slab ingots, and range from 20 to 48 inches wide, $\frac{5}{16}$ to 2 inches in thickness, and up to 150 feet in length. The largest output in twenty-four hours has been 576 tons. There are six heating furnaces in two rows, between which are the charging and drawing machines. The furnaces are regenerative with hearths $8\frac{1}{4}$ by $36\frac{1}{4}$ feet, and have four 6-foot doors each. The horizontal rolls in the mill are 30 inches in diameter, and the vertical rolls $17\frac{1}{2}$ inches. They are driven by a 50 by 60 inch reversing engine, direct connected, and are commanded by a 50-ton crane of 70 feet span. There are two hot beds, one on each side of a line of live rollers, and the plates are moved along the beds by endless chains. Vertical water-tube boilers with mechanical stokers are used for raising steam.

A description of new rolling mills at the Homestead Steelworks of the Carnegie Company also appears elsewhere.†

Rolling Rails.—R. W. Hunt ‡ returns to the subject of the temperature for finishing the rolling of rails. At the Edgar-Thomson mill the heat of the rails when placed on the cooling table was 1762° F. on the average, and on leaving the rolls it was 1580° F. At the M'Kenna re-rolling mill at Joliet, the rails were drawn from the reheating furnace at 1750° F. and finished at 1480° F. Reference is made to the method of equalising the temperature by placing the rails head to flange on the cooling table, and it is suggested that the heavier standard sections of the American Society of Civil Engineers may be modified in view of this practice.

The chemistry and heat treatment of rails are also discussed by W. R. Webster.§

At the Edgar-Thomson Steelworks experiments are being made with a rail-rolling process. The reheated blooms are roughed down in five passes, and then receive five passes on a second or intermediate train. Then they are removed for a short time to a cooling bed, where

* *Iron Age*, December 27, 1900, pp. 1-2.
† *Stahl und Eisen*, vol. xxi. pp. 123-125 ; one illustration.
‡ *Transactions of the American Institute of Mining Engineers*, Richmond Meeting, February 1901.
§ *Ibid.*

they are laid on their sides, so that the head of one rail is kept close up against the flange of the rail in front of it with a view of equalising the temperature. From the bed they are drawn off in succession and passed through the finishing mill at a lower but a more even temperature than usual.* A plan, side view, and section of the cooling bed are given to show the arrangements for moving the rails, so that only one is taken off at a time. Microphotographs of the rail are also appended.

A. W. Heinle † discusses the advantages of the method of equalising the temperature in the head and flange of the rail by laying them in contact for some time during the rolling. In this way the excessive curvature is avoided, and rolling is finished at a more even temperature.

P. Egermann ‡ discusses some American modifications of the rail rolling process. The first considered is the Kennedy-Morrison method.§ Before describing this the author points out that despite the attention given in recent years toward attaining chemically a correct composition for the rail, the results have not been wholly satisfactory in practice. There can therefore be no doubt that a large part of the difficulties experienced is more due to the physical condition of the rail than to its chemical composition. The larger rail sizes now employed, and the great accumulation of metal in the rail-head, cause the metal in this to remain much hotter after being rolled than was the case with the relatively small-headed rail of former years, produced, too, in slower working mills. To improve the quality of the rail it is scarcely to be doubted that the rail-head should be rolled at a lower temperature than that now customary. This is what is attained in the Kennedy-Morrison method. The claims made for this particular process are, however, somewhat disputed by the author.

The McKenna process for re-rolling old rails is subsequently dealt with by the author.

A plan of the Joliet mill in Illinois, for re-rolling steel rails by the McKenna process, has appeared,‖ together with illustrations of the rail-grinding machine, the charging machine, and the drawing device for the heating furnace, the rail transfer table, the cambering rolls, and the straightening department.

* *Iron Trade Review*, December 20, 1900, pp. 10-12; January 24, 1901, p. 18; *Engineering News*, vol. xliv. p. 437.

† *American Manufacturer*, vol. lxviii. p. 109.

‡ *Stahl und Eisen*, vol. xxi. pp. 220-224, 295-300; sixteen illustrations.

§ *Iron Age*, December 20, 1900, pp. 16-18.

‖ *Ibid.*, January 17, 1901, pp. 6-11.

Rolling Thin Sheets.—A method of hot-rolling metals of different kinds down to very thin sheets, known as the Allis-Andrew process, has been perfected in Bridgeport, Connecticut. A number of strips are coated with a composition to prevent them from sticking, and are riveted together at the leading end. They are very carefully and uniformly heated in a gas-fired furnace, and are rolled in a two-high 8-inch mill. The majority of the experiments have been made with 4-foot strips $\frac{1}{16}$ inch thick and10 inches wide. After the first pass the steel has been reduced to an average $\frac{27}{1000}$ inch thick, the elongation being from 4 feet to 7·95 feet. The second pass has carried the thickness down to an average of $\frac{15}{1000}$ inch, the elongation being to 13·80 feet, while the stock after the third pass had been reduced to an average of $\frac{11}{1000}$ inch, and the elongation brought to 18·76 feet, the spread from first to last being $\frac{3}{8}$ inch, so that the stock would trim close to the original 10-inch width.*

Rolling Tin-Plate.—In a discussion on the size of tin-plate rolls, it is pointed out that the preferred diameter in the United States is 26 inches, and that in Welsh practice it does not exceed 16 to 18 inches as a rule. The wearing surface is also larger, and the radiating power of the roll has increased directly as the diameter; the heat-losing tendency of the roll has increased as the square root of the increase in roll diameter, with the same speed of the pack, and the speed of the pack may be increased as the square root of the increase in diameter, thus reducing the heat-losing action of the pack by the same amount that it was increased. It would follow that the speed of the large rolls could be increased sufficiently so that the pack would lose no more heat to them each pass than to the small rolls, and there would be left as a net advantage the direct increase in heat-radiating power of the larger roll, permitting a proportionate increase in the number of passes per hour. There would also be this advantage, that the pack travelling at a greater lineal speed would consume less time for the entire pass, and would thus, during the pass, lose less heat to the air. Against this is the disadvantage that the larger the roll the greater the difficulty and the more time employed by the catcher in returning the pack to the roller over the top roll. In increasing the roll diameter, the point would soon be reached where it would make the work very hard indeed for the catcher. The flow of the metal is impeded by the larger diameter, but to an unknown amount, while the

* *Iron Age*, November 1, 1900, p. 25; *Iron and Coal Trades Review*, vol. lxi. p. 990.

action of small rolls is more akin to that of the dies in wire-drawing, so that there is some point where further increase is undesirable. The large roll requires more time to heat up, but it maintains a more even temperature. It requires more power to drive. Breakage is mainly due to internal strains due to heat variations and to imperfections in the castings themselves. Whether the latter can be overcome in very large rolls is uncertain.*

Wire-Rod Rolling.—According to W. Garrett,† one wire-rod mill at Joliet made an average of 201 tons of No. 5 rod during forty-eight turns in December 1900, and next month the Rankin mill averaged 204·6 tons during fifty single turns of eleven hours each, or 10,230 tons in all, this making the record. It may be remarked that 204 tons of No. 5 rod measures 750 miles in length. The reduction of wages paid per ton to the rollers is discussed. The same author also ‡ discusses the 4-inch billet, which has so many advantages, and has replaced all other sizes in the United States for wire-rod rolling. At the same time, he confesses himself to be much impressed by the use of 5, 6, or even 7 inch blooms rolled direct into rod by certain German makers. The use of the 4-inch billet is advocated instead of the smaller sizes used in England.

Rolling Seamless Pipe.—Illustrations are given § of the Bartlett-Kent rolling-mill for seamless pipe from 12 to 30 inches in diameter and $\frac{1}{8}$ to $1\frac{1}{4}$ inches in thickness from hollow ingots on a mandrel. This mandrel carries three convex rollers, and three concave rollers parallel with the former bear on the external surface of the pipe. The latter rolls are driven, and are arranged to be fed inwardly on radial lines as the metal extends.

Works Locomotives.—M. Büttner, ‖ in referring to the application of electricity as a source of power, considers it as a motive agent, and describes various types of works locomotives driven by the aid of accumulators.

* *Tin and Terne*, November 1, 1900, p. 5.
† *American Manufacturer*, vol. lxviii. pp. 225–226.
‡ *Ibid.*, pp. 353–355. See the author's paper in this volume.
§ *Iron Age*, April 25, 1901, pp. 6–9.
‖ *Stahl und Eisen*, vol. xx. pp. 1108–1116; nine illustrations.

[redacted]

PRODUCTION OF STEEL.

CONTENTS.

I.—*THE CARBURISATION OF MALLEABLE IRON.*

The Direct Production of Steel.—C. Otto * observes that a comparison between the work done at a blast-furnace at Pueblo with another at Leadville, 5000 feet higher up, showed that the latter consumed considerably more coke than did the former furnace. At first the cause of this was not generally recognised, and the fact led to much discussion. The diminished air-pressure, however, leading to a lower degree of intensity in the reduction process, must be held to be the cause. If 1·428 kilogramme of finely divided iron oxide is mixed with 0·321 kilogramme of pure carbon, and heated in a covered crucible in a wind furnace, one kilogramme of malleable iron should result with a relatively small consumption of fuel. Theoretically, 1770 calories are required for this, of which 794 are obtained from the combination of the carbon added with the oxygen of the ore, the outer firing being, therefore, only called upon to yield an additional 976 calories. If the carbon monoxide escaping from the crucible could be burnt satisfactorily to carbon dioxide, 1800 additional calories would result, a quantity not only enough to provide the external heat required, but to leave a considerable excess unutilised. There seems but little to stand in the way of a rapid process of reduction being capable of development in this way. Practice and theory do not agree in this case, however. If a good external heat is maintained, the

* *Chemiker Zeitung*, vol. xxiv. p. 1033; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlix. pp. 61–64.

reduction proceeds at first rapidly, a chemically pure iron sponge resulting. Soon, however, the reaction begins to slacken, and comes gradually to an end, before the whole of the ore has been reduced to the metallic form. It usually takes six hours before this method can be completed. An unsatisfactory yield, long duration of the reduction process, and large consumption of fuel consequently lead to the process being a disadvantageous one, although very many attempts have been made to improve it and to make it a practical process. The author refers to the Siemens rotating furnace, pointing out that if he was unable to make his experiments successful, even though using an excellent system of gas-firing, it must be generally recognised that the method is not a practicable one. What was gained in one direction was lost in another. By raising the temperature the action of the carbon monoxide was, it is true, so increased as to enable it to exert a stronger action on the oxygen of the ore. On the other hand, it went beyond this, the increased temperature resulting in a degree of expansion being reached at which the gas is unable to act on the oxygen of the ore. Under these circumstances, the proposal to keep the volume of the carbon monoxide a constant one seems sensible. This means increasing the pressure. Calculating from the heat of combustion of iron, which is now placed at 1352 calories, and the specific heat of iron oxide, one obtains $\frac{1352^\circ}{1{\cdot}428 \times 0{\cdot}17} = 5569^\circ$. This temperature must be reached during the reduction if this is to take place in the same time as was expended in the oxidation. If more time is allowed, then a proportionately lower temperature is needed at first, but the complete reduction is scarcely possible if the high temperature that results at the oxidation is not attained. Strong external heating is therefore necessary. The author deals further with this subject from a theoretical standpoint. He then proceeds to point out that by the use of pressure the carbon monoxide reducing agent may be caused to yield higher temperatures. Doubling the pressure means doubling the rapidity of the reduction. Thus, if at atmospheric pressure six hours are needed for the complete reduction of the ore, this can be reduced to three hours by using a pressure of two atmospheres—provided, that is, that the surface of the ore exposed to the action of the gas is adequate: this can be attained by using finely divided ore. The external firing should also be effected at a similarly increased pressure. The author refers to some earlier experiments of Bessemer and others in this direction.

Direct Production of Steel in India.—C. Ritter von Schwarz * observes that the manufacture of iron and steel was undoubtedly known to the inhabitants of Hindostan before it was to those of Europe. In the burial-places of Wurri Gaon, in the Central Provinces, the date of which reaches back to 600 B.C., fragments of cast steel weapons have been found in the coffins. In the Rigveda, which was written some 3000 years ago, it was stated that the god Indra used iron for his weapons and armour. Slag heaps and old mine workings are found all over India wherever iron ore exists, and afford testimony that the manufacture of iron and steel was carried on on a considerable scale, although at most of these places it has at present quite died out, as well as even the tradition that iron was ever made there. It has been proved that the "Wootz" steel was exported from India to Western countries 2000 years ago, and that all attempts to produce this excellent steel elsewhere have been failures. Hyderabad and Mysore were the chief steel-producing districts. In addition steel was, and is in part still made, at a number of places which the author names. The metal for the famous Damascus weapons of the Middle Ages was not made at Damascus, but at Kona Samundrum, near Nirmal, now an unimportant place in Hyderabad. Hence Persian merchants took it on mules through Central India, the Punjab, Afghanistan, and Persia, to Damascus. In an old Indian manuscript, the "Aini-i-Akbari," the method of manufacture is described. Fine grains of magnetite were separated from the schist in which they occurred, by crushing and washing. If the rock was too hard it was first calcined. This preliminary treatment took place at Dimdurti, not far from Kondapour, where the iron ore deposits were. The other "brown" ore—brown hæmatite—came from Mirtapelli, near Nirmal, to the south of the Godavari. The smelting-furnaces were at Kona Samundrum, also near Nirmal. Three parts of grey ore—magnetite sand—and two parts of the brown ore were mixed with charcoal and placed in a crucible, on the bottom of which a piece of glass slag had been placed as flux. The crucibles were of fireclay kneaded with oil, cow-hairs, and rice husks. They were then carefully dried and burnt. The mixture of ore and charcoal powder was only allowed to about half fill the crucible, to avoid losses. On the top of this were placed a few leaves of convolvulus lauriflora or calotropis gigantea. Then the crucible was covered with a well-fitting conical fireclay cover. This cover had in the middle a small round opening that could be closed with a fireclay plug. This served the

* *Stahl und Eisen*, vol. xxi. pp. 209–211, 277–283, 337–341, 391–399, with illustrations.

workman as a means of ascertaining how things were progressing inside the crucible. This latter was then placed in a round furnace, surrounded with charcoal, and then blowing was kept up for twenty-four hours by means of four double-bellows, at first slowly and carefully, and finally, when the contents of the crucible had began to melt, the blowing was effected rapidly. As soon as the fusion began the worker in charge kept a careful control over the process to prevent the steel from being heated longer than was absolutely necessary. For this purpose he inserted at intervals a small iron rod through the hole in the crucible cover and stirred the mass together. As soon as the correct stage had been reached the blowing stopped, and the crucible allowed to cool down in the furnace as slowly as possible. The crucible was then broken, and the reguius of metal it contained collected. This was freed from slag and clay particles, and the metal being extremely hard was submitted to a tempering process. For this purpose it was stirred into a mixture of powdered brown iron ore and water, dried, and slowly heated. This tempering process was repeated until the right degree of hardness or decarburisation had been reached. This was verified by the worker by hammer and chisel in the presence of the purchaser, who watched the whole process from beginning to end. The Persian merchants often attempted to repeat the manufacture of steel of this quality in Persia, knowing thoroughly as they did the method employed. They were, however, always unsuccessful, and even nowadays, too, no one else can make it. The old workers adopted the very best means to ensure a perfect steel. Their art, therefore, had reached a condition of perfection 2000 years ago.

The ores used were quite free from phosphorus and sulphur, and only contained extremely minute quantities of copper. The occurrence of cold or red shortness as a consequence of faulty chemical composition was therefore eliminated. The price which the Persian merchants paid for this metal was about 9d. for each regulus. This latter weighed about 1½ lb.

The steel made in Mysore was also of excellent quality though less renowned. Here the method in use differed slightly from that just described, the crucibles, too, being much smaller.

A kind of cement steel was made at Bundelkund in Central India, in a manner which the author describes.

The method still practised by the natives in the more out-of-the-way parts of India is always the direct reduction of iron from its ores on a scale so extremely small that it is sometimes almost laughably so. The

quality of the metal produced is extremely good, but the expenditure of labour and materials is enormous when compared with the results attained, and the process generally a most irrational one. The author describes, with the aid of a series of illustrations, such a native iron-works of Central India. The method itself is that of the old Stück-ofen on a small scale. Five men produce daily about 200 lbs. of "iron," which is further treated in a primitive form of smith's fire, and is subsequently worked up into hoes, shovels, &c., the finished products weighing little more than about one-half that of the "iron" resulting from the first reduction of the ore. This further treatment necessitates the employment of six men and four boys. Between them the eleven men and four boys earn considerably less than five shillings a day. The total consumption of charcoal is between nine and ten times the weight of the finished articles. Owing to the low rate of wages and to the nature of the plant used, the price at which the iron is sold is very low, and the native metal is as cheap and fully as good as the Swedish, Lowmoor, and other irons with which it has to compete in the native markets.

The author next gives illustrations showing the interior of native ironworks in Western Bengal and Orissa. Bellows worked by the feet are used. These are worked in pairs, a man standing in front on them and a woman behind clasping him round the waist. The man uses his naked feet as the clapper, keeping his feet on the holes, through which the air enters, and lifting them and shifting his weight from one to the other bellows as may be necessary, a bent bamboo being used as a spring for the bellows. Another illustration shows a primitive ore-washing plant, a mountain stream being used for this purpose. The author refers to the Delhi column as a proof that the iron industry existed at one time on a far more important scale amongst the native inhabitants of India than it does now, but even tradition is silent on this matter. This column was constructed in the fourth century A.D.

Crucible Steel.—J. B. Johnston * states that open-hearth steel is replacing crucible steel in America. The latter material was mostly made from Swedish raw material, which was largely absorbed by Great Britain, and American substitutes were sought from their own charcoal furnaces, and later from the improved products of small converters and the open-hearth, with such success that the raw product tends to replace the crucible-treated material.

* *American Manufacturer*, vol. lxviii. pp. 242–243.

E. Schmatolla * describes his form of crucible steel furnace. In this the waste gases are used as a source of heat. The modification now described consists of a system of two crucible fires and a recuperator shaft for the preheating of the air to be used for the combustion of the fuel. The products of combustion from the first crucible fire pass into the next hole near the top of the crucible, and taking a downward course, escape near the bottom of this second hole. They then pass up a shaft around tubes down which cold air is forced. They subsequently escape into the stack. The plant generally is briefly described.

Steel-Casting Foundries.—An illustration † is given of the interior of a steel-casting foundry at Chester, Pennsylvania, to show the electric travelling cranes, of which there are five, all of 60 feet span, commanding a floor space of 33,600 square feet. Two of these are of 30 tons capacity, one of 25 tons, and two of 10 tons.

Three illustrations are given ‡ of a new steel-foundry at Kendall Station, near Pittsburg. There are two 10-ton melting furnaces, and the works are equipped with electric cranes, and all tools are also driven with electro-motors. A plan and illustrations of the charging side of the furnaces and of the core-room at the steel-foundry at East St. Louis, Illinois, are also given. § It contains four 15-ton tilting Wellman furnaces and a charging machine.

A general and profusely illustrated account of several large iron and steel works is given, ‖ including Lord Armstrong's Elswick works, by B. Taylor; the Carnegie works, by C. M. Schwab; the Krupp establishments, by E. Schroedter; the Westinghouse and Bethlehem works, &c.

Illustrations ¶ are published of a new German works for making steel castings. It is provided with three 15-ton open-hearths.

Centrifugal Casting.—A. E. Fay ** deals with the history and practice of centrifugal casting, adding many facts to the similar account of this subject given by E. Lewicki.†† The earliest patent

* *Stahl und Eisen*, vol. xx. pp. 1136-1137; one illustration.
† *Iron Age*, April 18, 1901, p. 7.
‡ *Iron Trade Review*, November 15, 1900, pp. 14-15.
§ *Ibid.*, December 20, pp. 13-15.
‖ *Engineering Magazine*, vol. xx. pp. 490-550.
¶ *Stahl und Eisen*, vol. xx. pp. 1181-1186; six illustrations.
** *Iron Age*, February 28, 1901, pp. 15-18.
†† *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xlii. pp. 719-724.

recorded is that granted to A. G. Eckhardt, of the Royal Society, in 1809, followed in America, by T. G. Lovegrove in 1848. Of the various designs there are four classes, according to the plane of rotation in relation to the axis. Several forms of apparatus are described more or less in detail, but special attention is given to the apparatus of Huth, and of Sebenius. Centrifugal casting has been used in the manufacture of pipes, of composite railway wheels, of ingots free from blowholes in the steel industry, and very largely for other metals, but the total product does not appear to be great.

Additions to Steel.—In place of using the ordinary manganese or other alloys as a deoxidising addition for steel, it is proposed to use a multiple alloy containing about 5 per cent. of aluminium, 10 per cent. of manganese, 10 per cent. of silicon, and 75 per cent. of iron, with the view of producing a more fusible and readily separated slag. Boron may be substituted for the silicon. It is stated that the Krupp Company have obtained control of this method.*

W. G. Irwin † states that about 500 lbs. of ferro-titanium are being made at Niagara daily, and used in steel manufacture.

II.—*THE OPEN-HEARTH PROCESS.*

Modern Forms of the Open-Hearth.—R. M. Daelen ‡ and L. Pszczolka observe that since its first use by Martin for the melting of ingot iron, the Siemens open-hearth has been considerably modified in form, although the system itself has always been maintained. At the commencement attention was directed mostly to the shape and measurements of the fusion space, and also to the entrance channels for gas and air. Only later on was attention directed to the regenerator chambers. The raising of the roof by F. Siemens, and the separation by Batho of the entrance channels from the fusion space, were important changes, while the increase in length of the hearth was a modification that ensued naturally from practical experience, as a means to a better utilisation of the heat, and as enabling the out-turn to be increased. Batho's change proved that only one opening for air and one for gas was necessary at each side, and when the cylindrical

* *Iron and Coal Trades Review*, vol. lxi. p. 1108.
† *Iron Trade Review*, January 10, 1901, p. 17.
‡ *Stahl und Eisen*, vol. xxi. pp. 50–54.

regenerator chambers of Dick and Riley were added, the assumption was justified that the form of the open-hearth had reached a high degree of perfection. The out-turn, too, was so considerable, that even now it is not exceeded, as far as the number of fusions per day and coal consumption are concerned. The depth of the bath was reduced to about a half, some 9 or 10 inches, and the number of charges worked off per day increased from two or three to five or six; while the coal consumption was diminished from 0·5 ton per ton of production to about 0·25 ton. These figures refer to charges in which much wrought or ingot iron scrap and relatively little pig iron is used. The general adoption of the combined system of Batho and Dick and Riley was not, however, general, for reasons the authors refer to. The erection was too massive, and the cost for the framework too high, unless but little fire-resisting material was used. But a saving in this direction meant loss of heat by radiation. This had, too, the effect of being bad for the workpeople employed. The free pipes connecting the hearth with the regenerators were thin, on account of the space available being small, and the framing was apt to bend. German smelters consider that by retaining massive brickwork and regenerators of large cubic capacity, the furnace will work more steadily, and the repairs be less numerous, especially in connection with the furnace roof. The Schönwälder modification has done much in this direction, and in an editorial note it is pointed out that a similar kind of valve modification was suggested by J. von Ehrenwerth * in the eighties. The furnaces now customarily employed in Germany are a combination of all these various improvements. The depth of bath is about 10 inches, five to six charges are worked off daily, the consumption of coal is about 25 per cent. of the yield, and the roof lasts from 150 to 200 working days. It is not considered advantageous, from the point of view of the scrap used, to exceed a capacity of 25 to 30 tons, and this is only customary in other countries where the charge consists mainly of pig iron, especially in the United Kingdom, with a view to save wages and fuel. A similar saving would, however, result in a much more effective way from the use of charging appliances for cold materials and preliminary fining for molten additions. The desire to replace hand labour by mechanical devices led, in the United States about twelve years ago, to the invention of the tipping form of the open-hearth. The authors criticise this form severely. Amongst other advantages claimed for this form of furnace is, that the contents

* *Stahl and Eisen*, vol. xxi. p. 51.

can be partly removed and the remainder dealt with as desired. This is only of use in connection with steel castings or ingots for forgings, and is of no use at all for mass production, for which it is always most profitable to tap at once the finished charge into the ladle. The results attained in practice are on the whole unfavourable to the use of mechanical aids in furnace work. This is best evinced by the numerous attempts made in this direction with the precursor of the open-hearth—the puddling furnace. The simple puddling furnace successfully held its own against all the Danks, Pernot, and other forms, despite the fact that the necessity for the replacement of hand labour by mechanical appliances was far greater in the puddling furnace than it is in the open-hearth. In this connection the authors refer to the Talbot process, and they quote from the account of it which appeared in the *Journal of the Iron and Steel Institute* (1900, No. I.). They point out that Talbot said that Daelen admitted a probable loss by the duplex system of 12 or 13 per cent., which, compared with a gain of 6 or 7 per cent. by the Talbot process, showed a difference of 18 to 20 per cent., or 15s. to 20s. per ton. This remark the authors controvert, placing the gain at 15·05s. in the most favourable case, and considerably less in others. It is not merely in the Talbot process, however, they observe, that such a yield as 107 per cent. results by the use of ore, for it has long been found that in open-hearth practice the more ore could be reduced, the higher was the percentage of pig iron in the charge. Indeed this is shown by Riley's paper in the same volume of the Journal on "The Use of Fluid Metal in the Open-Hearth," who shows a yield of 103·6 per cent. By the use of the author's duplex method it is not possible to reduce so much ore in the open-hearth, as the metal charge with this only retains small quantities of carbon and silicon. On the other hand, to reduce the ore, heat is necessary, and this is obtained by the consumption of gas or coal in the open-hearth, while in the preliminary fining of most kinds of pig iron by the duplex method the high percentage of silicon present leads to an excess of heat resulting, which can be utilised by the addition of ore in their apparatus resembling a converter. The pig iron charged into an open-hearth usually contains 1 per cent. more silicon than is required for the preliminary fining. The authors consider that they can produce as good results financially as are attained by the use of the Talbot process, and they adversely criticise the use of a 75 or 100 ton furnace having an output of a furnace only about a third the size. They point out, too, that their own process is not the "duplex process," for they

use no Bessemer converter, and blow no air through the bath of molten metal. What they do is to blow hot air under low pressure on the surface of the molten metal. They contend that with a 25-ton furnace they get a 20 per cent. higher yield per week than would result from the use of the Talbot process, while the metal produced is of excellent quality, which they consider to be most unlikely when the Talbot process is employed. The latter process is further adversely criticised, and in conclusion the authors say that the tipping form of the open-hearth is not likely to become common in Continental practice.

R. M. Daelen and L. Pszczolka * give reasons against the introduction of the tilting open-hearth furnace and the Talbot process in Germany and Austria-Hungary. The claim for increased yield in the process and the cost of the tilting furnace are criticised from an adverse point of view.

C. Clausel de Coussergues † summarises the modifications introduced in the construction of the open-hearth furnace in recent years.

H. W. Lash ‡ describes the Talbot process, and compares the cost with that of the Bessemer process to its advantage. Other advantages are also summarised.

Electric Power in Steelworks.—Illustrations have appeared § of the overhead travelling electric ladle crane erected at Vickers Sons & Maxim's works at Sheffield by the Wellman-Seaver Company. The main trolley handles loads up to 100 tons, and an auxiliary trolley handles lighter loads up to 25 tons. The various movements are operated by five motors varying from 100 to 5 horse-power, and supplied with current at 220 volts.

Electrically Driven Casting Waggon.—A waggon to carry a 20-ton casting ladle actuated by electric power is described. ‖ It is only quite recently that electricity has been used as a motive power for this purpose. A balancing arrangement is adopted by which the ladle can be raised and lowered through a height of 13 feet. It can also be turned round and shaken, and indeed all three

* *Iron and Coal Trades Review*, vol. lxii. pp. 68–70.
† *Mémoires de la Société des Ingénieurs Civils*, 1901, pp. 479–492.
‡ *Iron Trade Review*, February 28, 1901, pp. 14–15.
§ *Engineer*, vol. xci. pp. 239–241.
‖ *Stahl und Eisen*, vol. xxi. pp. 275–277; three illustrations.

motions can be effected simultaneously. It is driven by two motors acting independently.

S. F. Walker * discusses the use of electricity in the manufacture of iron and steel in its various stages, and gives the following illustrations :—Magnetic separator ; Wellman-Seaver charging machine and its appurtenances ; cranes with electro-magnets for lifting ; electric charging crane at the South Bethlehem works ; electrically operated ore bridge ; bin-filling car and scale car at Youngstown ; electric locomotives for ladle trucks ; electric charging machine and overhead cranes and travellers at the Homestead Works ; electro-motors for raising and lowering the rolls at the Parkgate Works, &c.

L. Bell † also deals with the use of electro-motors in engineering works, and gives illustrations of various tools driven in this way.

Open - Hearth Door Hoist.—At the Parkgate iron and steel works ‡ pneumatic door hoists are used for the open-hearth furnaces.

English Open-Hearth Steelworks.—A general plan is given § of the works of Dorman, Long & Co. at Middlesbrough. At the Britannia Works there are seven open-hearth furnaces with capacities from 40 to 50 tons, and four 30-ton furnaces, one being basic-lined. Gas is supplied by twenty-four Ingham producers. The cogging mill is 42 inches, and there are 28-inch and 36-inch finishing mills, the former having electrically driven live rollers. Some illustrations of the electric plant, straightening rolls, and one finishing mill are given.

Canadian Open-Hearth Steelworks.—The Dominion Iron and Steel Company's works, of which plans and other illustrations are given,‖ consist of a plant of four blast-furnaces, ten 50-ton open-hearth furnaces, a 35-inch blooming mill and pit furnaces, 400 Otto-Hoffman coke-ovens, coal-washing and sulphuric acid plants, an essential oil by-product plant, and a large machine shop and foundry. The ore unloading and piling plant consists of four towers similar to those on the Montreal docks for handling coal, and the stockyard is 366 by 952

* *Engineering Magazine*, vol. xx. pp. 858–876.
† *Ibid.*, pp. 723–735.
‡ *Iron and Coal Trades Review*, vol. lxi. p. 1165.
§ *Ibid.*, vol. lxii. pp. 711–713.
‖ *Ibid.*, vol. lxi. pp. 1058–1060.

feet, with room for extension. The furnaces are 85 feet high, with 20-foot boshes, 11¾ feet in the hearth and 14½ feet at the stock line. They have twelve 6-inch tuyeres and Kennedy's top filling appliances. The stoves are of the Cowper type, 21 by 85 feet. In the engine-house are five blowing engines with high pressure cylinder 50 inches in diameter, low pressure 96 inches, and air cylinder also 96 inches with a common stroke of 60 inches. The metal from the furnaces will be taken in 25-ton ladle cars to a Heyl-Patterson pig casting machine, which has a capacity of 1600 tons per twenty-four hours, or hot metal may be taken direct to the open-hearth furnaces. The steel plant consists of ten 50-ton open-hearth steel furnaces. They are of the tilting type, and the Bertrand-Thiel process may be used. These are arranged in a continuous row, and metal may be put in the furnace from either side, or cold pig iron or stock may be placed in the furnace by two Wellman-Seaver charging machines. The product of the furnaces, which is estimated at 1400 tons per day, will be tapped into 50-ton ladles, from which it is poured into the moulds on cars.

The Dominion Iron and Steel Company owns the iron ore deposits in Conception Bay, Newfoundland.* The following are two recent partial analyses of the ore mines:—

	I.	II.
	Per Cent.	Per Cent.
Iron	54·43	51·84
Silica	9·34	13·00
Phosphorus	0·74	0·84
Sulphur	0·05	0·03
Moisture	1·50	2·50

The known quantity of available ore above sea-level is estimated at 25,400,000 tons. The company owns other ore deposits elsewhere. It is to be regretted that the physical character of the ore is not mentioned. The Canadian ores so far imported into Germany were in lumps, and cost at Ruhrort 13s. to 14s. Enormous coal deposits are available. One of these, the Sydney field, is estimated to contain over 2,540,000,000 tons of coal. The following are assays of coal and coke used by the company †:—

* *Iron Age*, November 8, 1900, p. 18; *Stahl und Eisen*, vol. xxi. pp. 55-62; seven illustrations.

† *Stahl und Eisen*, vol. xxi. p. 56.

	Raw Coal.	Washed Coal.
	Per Cent.	Per Cent.
Moisture	1·21 to 1·54	0·84 to 1·08
Volatile matter	30·86 „ 32·45	32·99 „ 37·86
Fixed carbon	60·45 „ 62·91	61·69 „ 62·60
Sulphur	1·50 „ 1·64	1·07 „ 1·17
Ash	4·69 „ 5·65	3·31 „ 4·50

The coke contains from 0·78 to 1·01 per cent. of sulphur and 5·38 to 6·24 per cent. of ash in the case of the various assay results given. It is stated to give satisfaction in the blast-furnace. The limestone used comes from the marble quarries at Clark's Core, and dolomite is obtained from George River. The works are quite new, and the Government in order to foster the industry has granted large premiums for the first four years. The works themselves are described.

American Open-Hearth Steelworks.—A. P. Head * gives an illustrated account of the new works of the Alabama Steel and Shipbuilding Company at Ensley, near Birmingham, Alabama. There are ten 50-ton open-hearth tilting furnaces of Wellman's design placed in a line in a building 748 feet long and 80 feet in width. The body of the furnace is approximately rectangular, instead of oval, and the neck containing the ports is movable, so that it can be drawn away when the furnace is being tilted. Each furnace has three charging doors, and the metal may be poured direct into the ladles, or through a fore-hearth attached to the furnace at the tapping-hole direct into the ingot moulds on trucks. This appliance has met with much success. Two Wellman electric charging machines are used. Gas is supplied by thirty-two producers. The ingot-stripper is electrically worked. The blooming mill is two high, with 44-inch rolls and electric screwing gear and live rollers also electrically actuated. A reversing engine, with two 36-inch cylinders and 48-inch stroke, drives the mill, being geared at two to one.

A plan and some illustrations have been published † of the new plant of the United States Steel Company at West Everett, Massachusetts, which is chiefly devoted to the manufacture of steel castings and tool steel. The main building is 200 by 120 feet, of which the centre, 58 feet wide, is spanned by electric cranes, and forms the

* *Iron and Coal Trades Review*, vol. lxii. pp. 553–557.
† *Iron Age*, January 17, 1901, pp. 1–4.

moulding and casting floor. One side contains the core ovens and on the other side are placed two 15-ton open-hearth furnaces. An adjacent building is furnished with a twelve-pot crucible furnace.

A plan of the steelworks at Granite City, Illinois, has been published, with an illustrated description of the works. In the scrap and material yard mill, scrap is not bundled, but is placed loosely in the charging boxes, and taken in trucks up an incline to the charging floor.* Altogether there are six 25-ton open-hearth furnaces. Raw dolomite is used. Ingots are cast on cast steel ingot trucks. Plates are rolled on a universal mill, designed for 8 to 36 inch plates, and there are a large number of sheet mills. The rolled material is used for making stamped and enamelled ware.

Some photographic illustrations, and a short general description of the works of the Bethlehem Steel Company, have appeared.†

Andrew Carnegie ‡ comments on the development of steel manufacture in the United States, chiefly from the future industrial point of view.

Japanese Steelworks.—An account is published by Wada § of a new steelworks just erected by the Japanese Government in the neighbourhood of Kokura, in the north-east of Kiúsiú. The works is designed to have an annual out-turn of 35,000 tons of rails, 25,000 tons of sheets, 15,000 tons of shapes, and in all above 90,000 tons of Bessemer and open-hearth metal in one form or another. It is anticipated that the cost of the ton of rails will be about £5, 14s., and the ton of sheets, £7, 1s. The ores will be brought from Hauyang, in China, and are stated to be of excellent quality. The works lie near the harbour of Wakamatsa, and are stated to be of the most modern type, the cost having amounted to about £140,000. It is anticipated that it will soon be found possible to still further enlarge the plant by laying down a mill for rolling armour-plates.

A recent consular report ‖ refers to the new iron and steel works in the north-western corner of the Japanese island of Kiusiu, near an excellent harbour and a railway. The works comprise coke-ovens and blast-furnaces; Bessemer, open-hearth, and steel foundry; roughing,

* *Iron Age*, January 10, 1901, pp. 12-17; with inset.
† *Iron and Coal Trades Review*, vol. lxii. pp. 183-185.
‡ *Evening Post*, New York: *Iron Trade Review*, January 24, 1901, pp. 20-21; *Iron and Coal Trades Review*, vol. lxii. p. 178.
§ *Stahl und Eisen*, vol. xx. p. 1063.
‖ *Engineering*, vol. lxxi. pp. 497-500.

rail, bar, sheet, and plate mills. The total appropriation of the Government is 14½ million yen, of which 4½ million have been expended.

III.—*THE BESSEMER PROCESS.*

The First Bessemer Rail.—A section of the first Bessemer rail has been presented to the Institute by Mr. Edward Riley, who has kindly furnished the following analyses:—

First Bessemer rail rolled at Dowlais in the autumn of 1856. Ingot made at Bessemer Works, at Baxter House, St. Pancras, London, from best Blaenavon foundry pig:—

	Per Cent.
Carbon	trace
Silicon	traces
Sulphur	0·235
Phosphorus	0·516
Arsenic	nil
Manganese	nil
Copper	nil
Iron	99·249
	100·000

Pig iron used for above Bessemer rail:—

	Per Cent.
Carbon	3·40
Silicon	1·36
Sulphur	0·07
Phosphorus	0·29
Manganese	0·28

The analysis of pig iron given above is not from the actual pig iron used; it is an analysis of the best Blaenavon foundry metal, such as was used by Bessemer in his experiments at Baxter House.

Small Converters.—H. Guérin * describes the small converter designed by T. Levaz, and used at Stenay in France. It is of the tilting type, with side blast, and the upper part is enlarged to form a pocket to receive the metal when the vessel is turned down. The charge of 3500 to 4000 lbs. is blown in twelve minutes.

Three 2-ton Tropenas converters have been installed at a works at Chicago Heights, and their capacity is rated at 50 tons per day. With

* *Engineering Magazine*, vol. xx. p. 1049.

an air blast of 3 to 4 lbs. pressure, the blow lasts sixteen to twenty minutes. Ferro-silicon or ferro-manganese is added to obtain the desired quality. Mild steel castings are usually made with a tensile strength of 65,000 to 75,000 lbs. per square inch, and an elongation of 20 to 30 per cent.*

Metal Mixers.—The Jones mixer patent litigation has reached the Supreme Court in the United States, and the briefs filed by both parties have been published.† On the one side it is contended that the direct process of Bessemer working with metal from the blast-furnace is only practically and commercially successful on a large scale when the mixer is used, and that the patent should be upheld. The other side contend that too much stress has been laid on this allegation, and that there have been anticipations of the practice both on paper and in practice. The American patent expired on June 1, 1901.

Mixed Steel Process.—R. B. Kernohan‡ proposes to meet some of the objections to the mixed Bessemer and open-hearth processes raised by H. H. Campbell, especially those relating to the cost of the preliminary treatment in the converter. Practically the method consists in replacing the ordinary converter by a special form consisting of a long inclined trough down which the metal is to flow from the mixer to the open-hearth. During its passage, the thin layer is subjected to a blast through a number of tuyeres directed up the slope so as to delay the downward flow, and thus the metal may be completely decarburised. The trough is covered over, and is to be made in removable sections with provisions to allow for expansion.

New American Bessemer Works.—Some details have appeared§ of the New Republic Steelworks at Youngstown, Ohio. Four cupolas, 24 feet high by 8 feet 7 inches in diameter, are placed in a three-storey building. The converters, of 25-ton capacity, are placed in a steel building 121 feet by 60 feet, and 50 feet in height, the ladles being brought to it from the cupola-house by a cable tramway. The blooming mill is designed for billets and slabs. Dimensions of the leading buildings are given.

* *Iron Age*, January 3, 1901, pp. 18–19.
† *Ibid.*, January 24, 1901, p. 10, and January 31, 1901, p. 22.
‡ *Ibid.*, January 31, 1901, pp. 10-11.
§ *Engineering and Mining Journal*, vol. lxx. p. 426.

FURTHER TREATMENT OF IRON AND STEEL.

Compressed Fluid Steel.—An improvement in the method of compressing fluid steel * has been practised with good results at St. Etienne. The metal is poured into moulds of a somewhat more abrupt taper than that usually given, and the hydraulic pressure is applied from below, forcing the metal upwards in the conical mould. It is claimed that this method is more effective than the original one, employed by Whitworth, of applying the pressure to the top surface of the metal in an ordinary ingot mould.

Some notes on the early history of the fluid compression of metals are given by A. E. Fay,† who shows that the process was first applied to the softer metals, such as lead and copper, at an early date.

Repairing Faulty Castings.—Some further account is given of the application of the Goldschmidt alumino-thermic method as applied to the welding of worn or broken parts. ‡ The application of this to rolls is specially referred to. Instead of having to go through the present lengthy and cumbrous method of softening the broken part, what is now done is, simply after heating the metal to be treated, to pour a little of what is called "thermite steel"—metal prepared by the Goldschmidt method—on to the broken face, and then to fill up the mould with whatever metal is to be used. Care must be taken to see that none of the alumina slag is left on the metal when this is poured. After pouring off the greater part, the last portion must be removed by an iron rod. Great caution must be observed in doing this, as, if this slag is left, faulty welding might result. To obtain an iron that will flow quietly, the addition of some manganese is much to

* *Bihang till Jernkontorets Annaler*, 1900, pp. 294-303.
† *Iron Age*, January 31, 1901, pp. 29-30.
‡ *Stahl und Eisen*, vol. xxi. pp. 23-24 ; one illustration.

be recommended. This is done by adding immediately after the removal of the slag some so-called manganese-thermite to the molten iron in the crucible. About 10 to 20 grammes of this for each kilogramme of iron is adequate. The addition must be made as rapidly as possible in order to avoid a lowering of the temperature. Any slag formed can be held back when the metal is poured. In the case in question the thermite steel was poured on the broken casting from three crucibles, each for the few minutes having three men to look after it—nine men in all, that is, for the three crucibles. Ingot metal as hot as possible was poured on immediately after the addition of the thermite steel and the mould filled up. The process has always been successful.

Electric Welding.—The various methods of electric welding are described, with the aid of thirty-five illustrations, by H. Braune. *

New Tool Steels.—The tool steel made by the Bethlehem Steel Company for cutting at a high speed almost regardless of the temperature, is stated † to contain at least 0·5 per cent. of chromium and 1·0 per cent. of tungsten or molybdenum, or a mixture of those elements. In some cases the percentage runs up to 5 or 6 per cent. The tools made from such a steel are first of all heated to a temperature of 1725° F., or in some cases to 1850° F. or more. They are then cooled rapidly by a lead bath to a temperature below 1550° F. The temperature should not be allowed to rise temporarily during the cooling down to 1240° F., but it may be held stationary for some few minutes preferably between 700° F. and 1240° F., or it may be reheated to those temperatures. A fusible slag is used to protect the metal from oxidation.

In a paper read by Reuleaux ‡ some further particulars are given of the Taylor-White tool steel, which was shown in operation at the Paris Exhibition by the Bethlehem Tool Works. When working on soft steel a remarkably heavy cut can be taken at a cutting speed of 150 feet per minute. This performance is partly due to the fact that the cut is not scraped off in the ordinary way, but split off, the action being similar to that of splitting off a wood chip with an obliquely

* *Jernkontorets Annaler*, vol. lvi. pp. 28–78.

† British Patent, No. 10,738 of 1900.

‡ *Verhandlungen des Vereins zur Beförderung des Gewerbfleisses*, 1900, pp. 179–189; illustrated.

held axe. The cuttings become red-hot, and the tool itself also heats considerably.

F. Heissig * observes that at the same time that the Bethlehem Steel Company in Pennsylvania were experimenting on an improved tool steel, as subsequently exhibited by them at the Paris Exhibition, Messrs. Böhler Brothers & Co. were experimenting in the same direction. The author now publishes the results of experiments made with a tool steel the firm has brought out. They were made by the author in November 1900. The first experiments referred to were made in cast iron, while others related to work done on a steel containing—

Carbon.	Silicon.	Manganese.
0·43	0·18	0·95

After nearly two hours' work on this latter steel the tool showed not the smallest sign of damage. Other experiments were made on ingot iron. Extremely high values were attained as to quantity of work done.

C. Caspar † states that in 1895 he observed that certain special crucible steels, when treated in a particular way, became very hard, and retained this hardness even up to a temperature which bordered on a dull red. Further experiments enabled the author to obtain a steel possessing the property of "natural hardness," which differed altogether from Mushet steel, and was much more workable. This steel possessed all the properties now claimed in connection with the Bethlehem and other tool steels of this type. The author now manufactures this steel, and he claims for it that perhaps it may not do quite so much work as some of these others, yet it possesses the great advantage over these that it can be hardened with extreme facility, and does not crack at all in the hardening. It can be readily forged and filed.

O. Thallner ‡ states that he visited the Bethlehem Steelworks, Pennsylvania, on behalf of the Bismarckhütte, Upper Silesia, which had obtained an option of purchase of the tool steel hardened by the Taylor-White process. In the British patent, No. 10738, 1900, this steel is stated to be produced by the additions of chromium, tungsten, and molybdenum, not less than 0·5 per cent. of chromium and 1 per cent. of tungsten or molybdenum, or a mixture of both, being

* *Stahl und Eisen*, vol. xxi. pp. 26–28.
† *Ibid.*, vol. xxi. pp. 75–76.
‡ *Ibid.*, vol. xxi. pp. 169–176, 215–220.

employed. If very hard metals are to be treated these additions are increased, at least 3 per cent. chromium, 6 per cent. of tungsten, and 3 per cent. of molybdenum being used. The carbon contents is of secondary importance, 0·85 per cent. Hardening in a lead bath increases the cutting power of the steel. The author describes a series of practical tests made by him with this steel at the Bethlehem Works on all sorts of metal. As a result the purchase was not completed. The author points out that chromium is capable of producing a "naturally hard" steel, and that tungsten and molybdenum are capable of producing a still greater degree of hardness in such a steel. It is a well-known fact that a "naturally hard" chrome steel must be heated to a very high temperature if it is to acquire its maximum degree of hardness. If such steel is allowed to cool down slowly in air from a very high temperature down to 600° C., and then maintained for a few minutes before further cooling, the exact time being one to be ascertained as the result of practical experience, and then rapidly or slowly cooled from the temperature, it becomes much more resisting to the influence of heating during work. The American tool required to be changed every twenty or thirty minutes when being worked at its maximum rate of speed, the cutting edge getting worn down. The steel is, too, very difficult to harden. It requires to be heated for a long time to a very high temperature before being rapidly hardened. This leads to the formation of cracks, which are almost impossible to prevent. The steel does not really possess great hardness, but rather great strength. The consequence is that it cannot be used for working up really hard metal. The result is that this tool-steel might be of value at one works and not at another, according to the kinds of material that have to be dealt with and the products desired. The question has not yet been finally settled, whether it is not possible to produce a steel which shall possess all the good qualities of the Bethlehem steel without its bad ones. The author deals generally with the theoretical as well as with the practical side of the subject.

Practical results attained with the mark L tool steel of the Bergischen Stahlindustrie works at Remscheid are now given.* These are stated to have been as good as, and in some respects better, than those obtained with the Bethlehem tool steel or with that of Böhler Brothers & Co., referred to in these abstracts. The results obtained with steel castings (III.) were notably high. This latter contained 0·37 per cent.

* *Stahl und Eisen*, vol. xxi. pp. 176-178; one illustration.

of carbon and 0·8 of manganese. The turnings per minute are given as follows in the case of the three steels above referred to:—

	Kg. per Min. I.	Kg. per Min. II.	Kg. per Min. III.
Bethlehem steel	...	1·040	...
Böhler Bros. steel	0·610	1·130	0·090
Berg. Stahlindustrie steel .	0·525	1·125	0·654

The partial analysis of III. has already been given; I. was a cast iron, and II. a steel with 0·13 per cent. of carbon and 0·521 of manganese.

Some interesting results of another German self-hardening tool steel are given.*

Hardening and Tempering.—A plan with a number of illustrations and sections of furnaces are given † of J. H. Williams & Co.'s hardening and tempering works at Brooklyn. All temperatures in the furnaces and in the oil and lead baths are controlled by pyrometers, and the times for heating are carefully regulated, so that colour determination plays no part in the work.

Charging Appliances for Re-Heating Furnaces.—The Lauchhammer Company ‡ has constructed a large number of the charging appliances for open-hearth furnaces that have been described in *Stahl und Eisen*. These have met with such appreciation that the same company has now designed a similar appliance intended for the charging of ingots, &c., into heating furnaces. Up to now this has usually been done by hand with very primitive appliances. The appliance now designed is described and illustrated. It is modified to suit furnace arrangements, three modified forms being described and illustrated, one being intended for cases when the heating furnaces are arranged in a single line with adequate room; the second when there is not space enough around the furnaces to enable the first form to be used, and the third is intended for cases in which either the furnaces are placed in two rows opposite each other, or in a semicircular or angular arrangement.

The Manufacture of Pipes.—L. Linder § refers to some modern modifications in the methods of manufacturing iron and steel pipes and

* *Stahl und Eisen*, vol. xxi. p. 300.
† *Iron Age*, February 7, 1901, pp. 1-5.
‡ *Stahl und Eisen*, vol. xxi. pp. 125-128; three illustrations.
§ *Bihang till Jernkontorets Annaler*, 1900, pp. 398-405.

fittings. The method of galvanising is also described. Both welded and weldless tubes are passed in review.

The increasing high pressures used in steam machinery, 10, 12, and 15 atmospheres being now by no means rare, have rendered the cast iron pipes and valves formerly used no longer applicable. The Verein Deutscher Ingenieure * has consequently, as the result of experiments and careful calculations, now issued a series of tables and drawings dealing with pipes, valves, &c., that are suitable for use with high pressure steam.

Steel Rails.—It is stated that 220 tons of nickel steel rails were made for the Pennsylvania Railroad Company and are being tested on the Horseshoe curve. The average composition is—

C.	P.	Mn.	Ni.
0·504	0·094	1·00	3·22

The metal was somewhat red-short in rolling, and very rigid and hard when cold.† So far they show very little wear.

Railway Waggons.—Dimensioned illustrations are given ‡ of the 25-ton double bolster waggons now being built in considerable numbers at the works at Darlington and at Openshaw, Manchester.

Some illustrations have appeared of the works and plant of the Pressed Steel Car Company. §

Steel Sleepers.—In an editorial article, *Stahl und Eisen* ‖ considers the question of ingot metal sleepers as discussed at the International Railway Congress. Their use on the Gotthard Railway, and the comparative tests made by Renson on the Liége-Limburg line, have already been referred to in these abstracts. A. Moreau ¶ has recently described the progress that has been made in this direction, and the paper is now referred to at some length. Estimating the total length of railway lines in the world at 900,000 kilometres (say 621,000 miles), the total number of sleepers required for this length of line is about a thousand millions. Allowing 0·35 shilling as being the average cost of maintaining and renewing each sleeper, this amounts

* *Stahl und Eisen*, vol. xx. p. 1239.
† *Iron and Coal Trades Review*, vol. lxii. p. 140.
‡ *Ibid.*, vol. lxi. pp. 1272–1274.
§ *Iron Trade Review*, February 14, 1901, pp. 11–14.
‖ Vol. xx. pp. 1148–1151.
¶ *Mémoires de la Société des Ingénieurs de France*, 1899, pp. 672–689.

to 350 million shillings, or £17,500,000 per year, or £47,900 per day. Any reduction on the average cost per sleeper means, therefore, a very great saving. Of the various kinds of metal sleepers that have been tried, a number have given unsatisfactory results for one reason or another. Among the most important of the comparative tests that have been made are those that have been carried out on the Netherlands Railways. It has been found that the use of round holes in sleepers for the bolts has greatly increased the life of the sleeper as compared with those in which the rectangular bolts necessitates angular holes. The improvements made in the shapes of the sleepers used are referred to, and the influence of rusting is next discussed. This has been found to be of practically no importance. In the year 1865, on the Deventer-Olst line of railway in the Netherlands, 10,000 iron sleepers were laid down. Since then over 200,000 trains have passed over these sleepers, and yet, after being thirty-five years in use, they are thought likely to last for a number of years. Other points connected with the use of such sleepers are generally passed in review, and all seem to point to their advantage as compared with wooden sleepers. Except under some special circumstances, cracks do not show themselves at the bolt holes if they have been drilled. Details are given as to the number of ingot iron sleepers that are in use. There are over a million and a half of the Post variety in use at the present time. The number in use is steadily increasing, and if the railways of Canada and the United States are left out of consideration, it may be estimated that about 20 per cent. of the remainder have now ceased to employ wooden sleepers or ties, and used metal ones only.

Structural Ironwork.—The erection of the Alexander III. bridge crossing the Seine at the Paris Exhibition in a single span of 357 feet, and that of the great dome, 141 feet in diameter and 128 feet in height, of the Schneider pavilion, are described by Michel Schmidt.*

The construction of the Alexander III. bridge has been described in great detail in an exhaustive work by Résal † and Alby.

Some iron structures at the Paris Exhibition are described by Frahm.‡ These are dealt with at length, and the description is accompanied by numerous dimensioned illustrations.

* *Mémoires de la Société des Ingénieurs Civils de France*, 1900, p. 299.

† *Notes sur la Construction du Pont Alexandre III.* Paris, 1900. With Atlas.

‡ *Stahl und Eisen*, vol. xx. pp. 1158–1165, 1212–1219, and 1274–1285, with 75 illustrations.

The construction of the tower of 300 metres, and the scientific work executed in connection with it, have been exhaustively described in magnificent volumes by G. Eiffel.*

The re-use of old girders, whether made of cast iron or of wrought iron, is somewhat dangerous, according to some recently published notes.† In some cases, the cast iron girders snapped when it was attempted to drill them, and many of them show dangerous defects upon careful examination. In wrought iron girders the holes are badly punched or misplaced, and have grooved owing to continuous movement. Examples of these defects are given.

Armour.—Recent progress in the manufacture of armour-plates is described by E. Delmas.‡ An idea of the magnitude of the appliances required for manufacturing modern armour-plates formed from ingots of 50 to 75 tons is afforded by an enumeration of the plant at the Le Creusot Works.

Baclé § gives some notes on the armour-plates exhibited at the Paris Exhibition, where five French firms, one English, two Russian, and one Italian firm exhibited. With the exception of compound plates, all classes that have been used were to be seen, and the author deals with each class in some detail. Iron plates are first reviewed, and then attention is turned to the various types of steel plates, including extra soft steel, special steels, hard steel, and cemented steel. Diagrams are given of a number of plates which have been tested, and the results of the tests are given.

The Manufacture of Ordnance.—Colonel J. P. Farley ‖ gives some notes, with numerous illustrations, on the manufacture of the 130-ton 16-inch breech-loading rifles being made at Watervliet arsenal, New York. These guns are intended for coast defence, and are expected to have an extreme range of 21 miles, with a muzzle velocity of 2300 feet per second. The rough forgings in the aggregate weigh 375 tons, and a list is given of the machine tools and other plant for their preparation. A vertical oil-heated furnace is used for heating the tubes preparatory to shrinking them in place. This con-

* *La Tour de Trois Cents Metres.* Paris, 1900. With Atlas. *Travaux Scientifiques Exécutés à la tour de Trois Cents Metres.* Paris, 1900.

† *Engineer*, vol. xc. p. 408.

‡ *Mémoires de la Société des Ingénieurs Civils*, 1900, pp. 320–329.

§ *Engineering*, vol. lxxi. pp. 66, 99, 131, 161.

‖ Notes on the Construction of Ordnance, No. 78, Washington, 1900.

sists of a firebrick cylinder with 13-inch walls, with steam oil spray burners in five rows of four burners each. The burners are placed tangentially, and are separately adjustable. The tube was made from an octagonal nickel steel ingot weighing 100 tons, of which the top 44 tons and the bottom 8 tons were removed before boring, and it was forged on a mandrel under a 14,000 ton press. The jacket was also forged from an octagonal nickel steel ingot weighing 245,000 lbs., and the hoops were made of fluid pressed steel without nickel. Tests of the material shows :—

	Elastic Limit. Lbs. per Sq. In.	Tensile Strength. Lbs. per Sq. In.	Elongation on 3 Inches. Per Cent.	Contraction of Area. Per Cent.
Tube . .	51,375	84,350	20·38	41·93
Jacket . .	52,250	87,800	22·16	48·32
Hoops . .	57,125	107,050	19·28	45·52

The estimated total time for the manufacture of each gun is given as 527 days, and the plant is designed to make three guns yearly.

P. M. Staunton * deals at considerable length with the forms of caps that have been applied to the noses of projectiles, and proposes some new forms. The action of the cap is discussed in detail.

The various types of French quick-firing guns, naval and field, are described in detail by G. Canet,† Honorary Member of the Iron and Steel Institute.

The Hardware Industry in Austria.—M. Zeitlinger,‡ in discussing the hardware exhibits at the late Paris Exhibition, also considers the question of the development of the hardware industry of Austria. At present this is at a somewhat low ebb and quite undeveloped. The author thinks that protective duties and other Government facilities ought to be adopted in order to further the progress of the industry.

The Policy of Scrapping Costly Machinery.—H. F. J. Porter § deals with the economic aspect of the question of keeping machine

* *Engineering*, vol. lxxi. pp. 336–339, 383.
† *Mémoires de la Société des Ingénieurs Civils*, 1900, p. 287.
‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlix. pp. 47–52.
§ *Engineering Magazine*, vol. xx. pp. 741–752.

plants up to date. The author considers that machinery, even if comparatively new, must be sacrificed without scruple and consigned to the scrap heap as soon as it is possible to replace it with a more efficient tool. It is only by rigorously adhering to this policy that manufacturers in these days can hope to maintain their position in the ranks of industrial progress.

PHYSICAL PROPERTIES.

The Crystallography of Iron.—In continuation of a former paper, in which the forms of crystalline masses of iron accidentally produced were described, F. Osmond * and G. Cartaud describe in great detail the nature of the crystals formed in the reduction of the metal from ferrous chloride by gaseous reagents at varying temperatures, corresponding to those necessary for the production of the different allotropic modifications of the metal.

The Coefficient of Expansion of Iron.—L. Holborn † and A. L. Day have determined the expansion of different metals at high temperatures by observing the change of length in a bar half a metre in length heated in an electric coil furnace. For a wrought iron bar the curve of expansion is a parabola up to 500° C., after which expansion increases less rapidly. With high carbon steel the expansion is more irregular. The results of the experiments and equations embodying the results are given.

The Microstructure of Iron.—J. A. Ewing ‡ deals generally with the structure of metals, showing that they have a crystalline formation and illustrating the orientation of the crystals. During strain the polished section shows that the metal yields by the slipping of the crystals over one another, but it always preserves the same crystalline structure. Even moderate heat, however, changes this structure and annealing has very marked effects. While annealing is in progress some of the crystals seem to invade their neighbours and to absorb them.

* *Annales des Mines*, vol. xviii. pp. 113-153. See *Journal of the Iron and Steel Institute*, 1900, No. II., p. 540.

† *American Journal of Science*, vol. xi. pp, 374–390; *Annalen der Physik*, 1901, p. 104; *Stahl und Eisen*, vol. xxi. p. 198.

‡ *Engineering*, vol. lxxi. pp. 82–83.

F. Osmond * gives a note, with illustrative micrographs, of some instances of superficial hardening produced by the rapid escape of gas through a small hole. The surface metal becomes highly heated and then is rapidly cooled by conduction. Nearer the extreme surface the carbon is diffused more and more but without reaching homogeneous distribution, since the original ferrite is still indicated by the presence of soft martensite

H. Le Chatelier † gives some notes on the technology of microscopic metallography with special reference to the polishing, etching, microscopic examination, and preparation of alloys. Small samples are cut with a hack-saw which is used so as to make the cut curved at the bottom. Polishing powders are washed with dilute nitric acid previous to separation into various grades of fineness by levigation and decantation in an ammoniacal solution. Alumina, flour emery, chromium oxide, and oxide of iron are used, but alumina is preferred. The abrading material is made into a paste with soap. Etching is best done in a neutral solution under the influence of an electric current, and the sample may be varnished with gun-cotton in amyl acetate. A special type of horizontal microscope is used with refracting prisms and the object piece vertical, and a mercury arc lamp is used as an illuminant to obtain a nearly monochromatic light.

H. J. Hannover ‡ casts soft alloys on a surface of mica instead of glass with good results.

J. C. W. Humfrey § gives some interesting micro-photographs of etched sections of iron produced by thermite as described by E. F. Lange.|| The surface is pitted with a geometrical pattern showing that the iron is built up of cubes. In some cases the cubes have a stepped form.

J. O. Arnold ¶ criticises the report of the Board of Trade Committee on steel rails, and gives micro-photographs of sections cut from the head, foot, and flange of the St. Neots broken rail, in different planes at different points. In his opinion this rail was rolled at a high initial

* *The Metallographist*, vol. iv. pp. 23-29.

† *Ibid.*, vol. iv. pp. 1-22.

‡ *Ibid.*, vol. iv. pp. 29-30; *Bulletin de la Société d'Encouragement*, 1900, pp. 210-211.

§ *Engineering*, vol. lxxi. p. 360.

|| *Journal of the Iron and Steel Institute*, 1900, No. II. p. 191.

¶ Lecture delivered before the Sheffield Society of Engineers and Metallurgists; *Iron and Coal Trades Review*, vol. lxii. pp. 765-767; *Ironmonger*, vol. xciv. p. 611; *Mining Journal*, vol. lxxi. p. 421.

temperature and was cooled very slowly. The effect of the sulphides is discussed.

J. A. Aupperle * gives some micro-photographs of steel taken from a circular saw broken in use and containing—

C.	Mn.	Si.	S.	P.
1·09	0·53	0·14	0·019	0·011

The constituents are considered to be correct except that the manganese was double what it should be, and probably the steel was poured when wild, as it shows a honeycombed structure.

Magnetic Properties of Iron and Steel.—R. L. Willis † has investigated the effect of temperature on the magnetic properties of iron and its alloys, and gives a number of curves to show the relationship of magnetising force, permeability, and temperature.

H. Kamps ‡ shows that the layer of oxide on iron affects the results of tests of the magnetic properties. The margins of annealed sheets are magnetically inferior to the centre on account of the oxide, though hysteresis tests apparently show opposite results.

G. J. Wells § gives a brief account of some of the methods used to determine the magnetic qualities of iron. There are four experimental methods which had been adopted for testing the permeability of iron. These are the magnetometric, balance, induction, and traction methods. The first two are of little practical importance. All the inductive methods depend upon the production of a momentary current in an exploring coil which surrounded the sample of iron to be tested, the magnetising force being produced by another coil having a known number of turns in which a known current is flowing. Amongst the various inductive methods are the ring method, which has been used by Stoleton, Rowland, Bosanquet, Ewing, and Hopkinson, and a variation on this system devised by Evershed and Vignoles; the bar method, which had been used by Rowland, Bosanquet, and Ewing; and the divided bar method, introduced by Hopkinson, the results obtained from which have been used very largely by electrical engineers. Dealing with traction methods, the author describes the devices introduced by Shelford Bidwell, and Silvanus Thompson, and the Ayrton and Mather apparatus, whereby both the permeability and

* *Engineering News*, vol. xlv. p. 162.
† *Philosophical Magazine*, vol. l. pp. 1-37.
‡ *Elektrotechnische Zeitschrift*, January 24; *Engineering*, vol. lxxi. p. 450.
§ Paper read before the Manchester Association of Engineers, November 1900.

hysteresis can be determined in a few minutes. A detailed account is also given of the permeability bridge, introduced by Ewing, for obtaining the magnetisation curve without the use of a ballistic galvanometer. Ewing's hysteresis tester is also described.

J. W. Esterline * and R. B. Treat gave the results of a large number of tests of the magnetic properties of American cast iron and steel, wrought iron, and sheet iron and steel used for electrical purposes. Over a hundred samples were tested, and the curves of B are given for values of magnetic intensity H up to 150, but the sheet metal was further tested up to values of 450, and the results are given in tabular form.

C. Barus † has investigated torsional magneto-striction in strong transverse fields and allied phenomena. The effect of longitudinal magnetisation is an increment of rigidity in all paramagnetic materials, whereas the permanent effect of a transverse or circular field is relatively inappreciable as far as rigidity is concerned. This conclusion is at variance with much of the earlier work on the subject, references to which are given. In a further paper ‡ the author discusses apparent hysteresis in torsional magneto-striction and its relation to viscosity.

J. Trowbridge § and E. P. Adams have experimented upon circular magnetisation and magnetic permeability. The permeability increases with full strength in spite of increase of frequency, but less rapidly than with steady currents.

P. Holitscher ‖ has studied the remanent magnetism with special reference to the duration of magnetisation and to the number of magnetic impulses applied. The remanent magnetic moment is dependent on the time during which the force is applied, and successive impulses in the same direction increase the remanent magnetism up to a certain limit.

P. E. Shaw ¶ and S. C. Laws give a short *resumé* of the present state of knowledge concerning the expansion and contraction of iron and nickel when magnetised and demagnetised, and then describe their own researches on the matter. Instead of using a ray of light as a lever to measure the change of length of the specimen, they employ a series

* *Electrical World*, through the *Electrician*, vol. xlvi. pp. 438–439.
† *American Journal of Science*, vol. x. pp. 407–418.
‡ *Ibid.*, vol. xi. pp. 97–110.
§ *Ibid.*, vol. xi. pp. 175–184.
‖ *Annalen der Physik*, 1900, No. 12.
¶ *Electrician*, vol. xlvi. pp. 649–651, 738–740.

of levers, which are set up by a micrometer screw until they close a telephone circuit, and thus are enabled to attain great precision.

Z. Crook * describes a yoke with intercepted magnetic circuit for measuring hysteresis.

A paper by Madame Sklodovska-Curie † on the influence of the chemical composition on the magnetic properties of hardened steel, and on the influence of hardening, tempering, percussion, and time, is given at length.‡

G. Belloc § discusses the thermo-electrical behaviour of soft iron containing but traces of carbon, steel with 0·3 per cent. of carbon, and hard steel with 1·25 per cent. of carbon. He finds for pure or carburised iron the formula $f\left(\frac{dE}{dt'}t\right)=0$ as representing the thermo-electric power for steel-platinum couples. The experiments were carried out at temperatures varying from 15° to 1200° C., an electric furnace being employed. The critical points observed were—

	A_1.	A_2.	A_3.
	Degrees.	Degrees.	Degrees.
Iron . . .	Not observable	740	870
Soft steel . .	700	780	780
Hard steel . .	660	660	660

In soft steel, therefore, A_2 and A_3 were identical, and so, too, in hard steel were A_1, A_2, and A_3. The author tabulates the results of his experiments, and shows how these varied with the temperature. The curves each show a maximum between two minima. The first of these latter occurs for all three samples at 470°, and they are approximately alike. The maximum for the soft iron was at 860°, that for the mild steel at 770°, and that for the hard steel at 650°. These closely approach, it will be seen, the respective critical points. Once these maxima were passed a diminution took place towards the second of the minima. This was at 940° for soft iron, 900° for mild steel, and 800° for hard steel. After these were passed a rapid rise again took place in each metal. For E in the formula given, lower values

* *American Journal of Science*, vol. xi. pp. 365–368.
† *Bulletin de la Société d'Encouragement*, 1898, pp. 36–76.
‡ *Stahl und Eisen*, vol. xxi. pp. 156–163.
§ *Comptes Rendus de l'Académie des Sciences*, vol. cxxxi. p. 336; *Stahl und Eisen*, vol. xx. p. 1128.

were attained on cooling than when heating, especially at the higher temperatures.

Hardness of Iron.—For testing the hardness of metals, especially of iron, W. J. Keep* uses an inverted drilling-machine, with the specimen practically balanced on the drill point and weighted to a constant quantity of 150 lbs. A straight fluted drill is used in preference to a twisted drill, and it is run at 200 revolutions per minute, but variation in speed does not affect the results as long as the drill does not heat or become too blunt. An automatic record is obtained by the descent of the drill moving a pencil over a sheet of paper which is traversed by gearing from the drill spindle. The angle between the lines made by the pencil when moving and when stationary gives a measure of the hardness. Under ordinary circumstances the angle does not vary more than about a couple of degrees in repeated tests, but it is very essential that the surface tested should be free from grit, and even that the hard skin should be drilled through or removed before the test begins. By attaching a tray under the drill the drillings may be collected for analysis. The author then gives a number of tests made in his usual style, with a varied assortment of specimens to show the effect of the different elements, and also refers to the shrinkage and chill. Increased silicon softens the metal, while combined carbon hardens it. The test can be made very rapidly.

J. A. Brinell † describes his experiments carried on for establishing the relative degree of hardness of materials. The specimens are subjected to the pressure of a heavy weight, a spherical steel ball of small diameter being interposed between the weight and the surface of the material. The diameter of the impression left on the surface forms a tolerably exact indication of the degree of hardness possessed by the objects thus tested. Tables appear showing the relative hardness of many metals ascertained by this method. It is asserted that by this means the carbon contents in steel samples can be accurately gauged, and the variations in the degree of hardness of steel, caused by successive heating and cooling, can be noted. It also affords a useful means of testing the uniformity of hardened steel productions.

Stribeck ‡ has carried out a number of tests to determine the per-

* Paper read before the American Society of Mechanical Engineers; *Iron Age*, December 13, 1900, pp. 16-19.

† *Teknisk Tidskrift*, vol. xxx. pp. 69-87; with illustrations. See paper by A. Wahlberg in this volume.

‡ *Engineering*, vol. lxxi. pp. 463-468.

missible pressure on ball bearings, and these give much information as to the strength of steel balls and of the surfaces on which they bear. They may be of interest in connection with the researches of Brinell, described in Wahlberg's paper in this volume.

Annealing Steel.—A. Campion * gives the results of further † experiments on the methods of annealing steel. Analyses of the steels treated show—

Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Arsenic.
0·174	0·075	0·033	0·057	0·560	0·036
0·180	0·121	0·050	0·073	0·590	0·026
0·167	0·075	0·041	0·055	0·460	0·037
0·360	0·075	0·038	0·039	0·752	...
0·313	0·093	0·047	0·063	0·600	0·041
0·440	0·093	0·037	0·074	0·580	0·087

These different steels were heated and cooled in various ways; bending and tensile tests were made, and the microstructure is described, and further experiments are promised. The value of the results in giving data for the performance of practical operations was pointed out in the discussion.

H. Fay ‡ and S. Badlam describe their experiments on the effect of annealing on the physical properties and the microstructure of a low carbon steel containing—

C.	S.	P.	Mn.	Oxides.
0·07	0·058	0·10	0·32	0·25

An electric resistance furnace, described below by C. L. Norton, was used for heating the samples, and the temperature was determined by a thermo-couple. The samples were allowed to cool slowly in the furnace. Tensile tests showed that the ultimate strength was fairly constant in bars heated below 850° C.; at 890° C. there was a sudden rise, and another maximum occurs at 1125° C., after which there was a decided fall. The curve of the elastic limit follows somewhat similar lines. The microscopic investigation does not show much owing to the very low percentage of carbon. Generally the results are akin to those obtained by Roberts-Austen with electrolytic iron.

* *Journal of the West of Scotland Iron and Steel Institute*, vol. viii. pp. 23-43, 83-92.
† *Journal of the Iron and Steel Institute*, 1900, No. I. p. 408.
‡ *The Metallographist*, vol. iv. pp. 31-53.

G. W. Sargent * deals with the effect of heat treatment on crucible steel rods 0·75 inch in diameter having the following composition :—

C.	Mn.	Si.	P.	S.
1·033	0·327	0·223	0·020	0·016

Micro-photographs are given to show the effect of heating to various temperatures, and also the results of tensile tests. As the temperature increases from the critical point 680° C., there is a decided loss in elongation and reduction of area. Reheating to 680° restores, as a rule, the properties of the steel heated to 1000° C. The results are compared with some obtained by Morse with 0·35 carbon steel.

C. L. Norton † describes some electric furnaces for laboratory use when steady and long-continued high temperatures are desired. In one form a clay pot is coated with magnesia and wound with a resistance coil of crinkled platinum wire, or with nickel wire if lower temperatures only are required. Another layer of magnesia is laid over the wire, and the whole is packed in a non-conducting composition. For still higher temperatures a clay muffle or a hollow carbon cylinder is surrounded with coke powder in which a pair of carbon poles are laid. By regulating the current passing through the wire or into the poles the temperature may be varied to any extent, and may be kept stationary. Several researches on the heat treatment of steel were made with these furnaces.

The Effect of Overstrain.—J. Muir ‡ has continued § his experiments on the effects produced on iron and steel by overstrain, and now deals with the tempering of iron thus hardened. If it is heated to any temperature above 300° C., it may be partially softened in a manner analogous to the ordinary tempering of steel, which is hardened by quenching from a red heat, and this applies to wrought iron as well as to steel, and possibly to other materials. A number of curves are given to show the effect both on the steel as received and also after it has been annealed at various temperatures. It is shown that the same temperature brought the yield point to approximately the same stress, no matter what might be the original hardness of the specimen under test, and that the harder the material was made

* *Transactions of the American Institute of Mining Engineers*, Richmond Meeting, February 1901.

† *Electrical World and Engineer*, through the *Iron Age*, January 3, 1901, pp. 22-23.

‡ *Proceedings of the Royal Society*, vol. lxvii. pp. 461–466, through *Engineering*, vol. lxxi. pp. 126–127.

§ *Journal of the Iron and Steel Institute*, 1899, No. I. p. 434.

by the tensile overstrain—that is, the higher the yield point was raised by permanent stretching—the lower was the temperature which could be shown to produce a slight tempering effect. Time also produces an effect, but the result is small compared with that produced by increase of temperature. All these results were also obtained with Lowmoor iron, and only differed in detail. Microsections of all the samples were examined, and in the course of this work a new method of staining the sections with moistened cocoa was made use of, and this is described.

The influence of time on the mechanical properties of iron and steel at the ordinary temperature has been studied by A. Le Chatelier.*

Testing Machines.—W. K. Hatt † and W. P. Turner describe the new impact testing machine at the Purdue University for testing specimens under tension or compression, the stress being applied by a falling weight. The tup weighs 515½ lbs., and it falls between a pair of columns about 12 feet high fixed on a base weighing 5000 lbs. A friction belt hoist and an automatic adjustable releasing gear are provided. The specimen is held between a pair of yokes, of which the upper one is fixed and the lower one is placed so that it is struck by the weight. Provision is also made for placing the specimen so that compressive or transverse stocks may be applied. An automatic recorder consists of a drum on which a curve is traced by a pencil attached to the tup; the drum is driven by a falling weight, and a tuning-fork arrangement traces a curve on it to record its speed. Careful tests have been made to investigate the energy absorbed by the various parts, and fully 95 per cent. are found to be taken up by the specimen. The apparatus will rupture a ½-inch diameter bar of mild steel, 8 inches long, with a single blow. At present an investigation is being made on the effect of temperatures from 100° F. to 400° F. on the resilience of metals. Specimens of these tests are given in tabular form.

S. B. Russell ‡ gives the results of tension impact tests made with a pendulum machine, and also the ordinary tensile tests for comparison in the case of different melts of Bessemer steel and of different kinds of wrought iron and steel. For a certain number of specimens, the resilience found by the diagrams taken on an ordinary testing machine

* "Communications présentées devant le Congrès International des Méthodes d'Essai," 1901, vol. ii. Part I., pp. 13-25.

† *Ibid.*, vol. i. pp. 507-521.

‡ *Engineering News*, vol. xlv. pp. 14-16.

is compared with the resilience found by the impact tests. The resilience is nearly always greater under impact than under gradual load, the gain showing an average value of 28·4 per cent. The form of the test-piece with nicks and with longer reduced sections is discussed, and also the losses due to the heat arising from the impact.

W. K. Hatt,* commenting on these tests, thinks that the impact test must stand on its own merits, and that the results are not comparable with tensile tests. Some of the advance results obtained from the Purdue machine are also given.

An improved form of the recorder for testing machines designed by G. C. Henning is illustrated and described.† A flat frame for the paper is now used instead of a cylinder, and a wider range is given to the machine by the arrangement of the multiplying levers, which are made adjustable, so as to give any desired scale.

C. Frémont‡ gives a long and interesting history of testing, with numerous extracts from the works of early authorities, illustrations of machines, and portraits of the originators of testing methods.

Testing Tool Steel.—Sergius Kern§ points out, that while many elaborate rules exist for testing structural steel, yet none, except a few empirical tests, are applied to ascertain the qualities of tool steel. Rules for this purpose might be developed by carrying out tests for a certain tensile strength and elongation at the same time that the steel undergoes the hardening and forging tests. These would better reveal the properties, and prevent the passing off of hard open-hearth steel as crucible steel, which happens more generally than is supposed. To indicate how definite rules might be established the author made some comparative tests with steel made by both processes, which gave the following results :—

	Carbon.	Tensile Strength.	Elongation in 2 inches.	Reduction of Area.
	Per Cent.	Tons per sq. in.	Per Cent.	Per Cent.
Crucible . .	0·60	45	12	30
,,	0·80	58	6	14
,,	0·90	62	5	12
Open-hearth	0·60	42	15	50
,,	0·80	50	12	28
,,	0·90	55	10	23

* *Engineering News*, pp. 82-83. † *Ibid.*, vol. xlv. p. 176.
‡ "Communications présentés devant le Congrès International des Méthodes d'Essai," vol. i., pp. 351-454.
§ *Chemical News*, vol. lxxxiii. p. 181.

Besides carbon the crucible steel contained :—Manganese, 0·25 per cent. ; silicon, 0·16 per cent. ; sulphur and phosphorus, 0·03 per cent. The open-hearth steel contained :—Manganese, 0·42 per cent. ; silicon, 0·08 per cent. ; sulphur, 0·01 per cent. ; phosphorus, 0·04 per cent. Generally speaking, hard open-hearth steel has less tensile strength than crucible steel of the same carbon contents, and shows a marked tendency to temper badly after hardening. It will always be found that the cutting edge of tools made of such steel is liable to crumble, a defect attributable to the high percentages of manganese which are always found in steels made by the open-hearth process.

C. Frémont * describes his method of testing iron and steel by bending small bars of square section.

Russian Specifications for Steel Castings.—The new specifications † for steel castings and forgings for mechanical purposes issued by the Technical Committee of the Naval Ministry are as follows :—Test specimens from steel castings must have an ultimate strength of not less than 28 tons, and not more than 37 tons, per square inch. The elongation in a length of 2 inches must be : (*a*) for steam pistons, high-pressure steam pipes, and for thin castings in general, not less than 12 per cent. ; (*b*) for all other castings, not less than 15 per cent. The specimens for bending tests must have a cross section 1 inch square, with a length of not less than 12 inches. Such specimens must be capable of being bent across a bar of not more than 3¼ inches in diameter, to an angle of not less than 45 degrees, in the case of articles enumerated in section (*a*), and to an angle equal to 230 – (5 × ultimate strength in tons) for those included under section (*b*).

In making large castings and also all important castings, the test-pieces are to be cast on the body of the casting itself, and annealed together with the latter before separating them. In no case are the test-pieces to be cut off and annealed separately. For small castings of similar shape, of not more than half a hundredweight in size, which are cast in groups, a test ingot may be cast separately.

The inspector may, if he thinks fit, take 2 per cent. of such small castings for making different tests, such as breaking, crushing, &c.

After passing all required tests, the steel castings are dropped from a height of 12 feet on to a concrete pavement, but the covering of thin parts and projections with a wood casing is permitted.

* *Revue de Mécanique*, 1900, pp. 421–458.

† Communicated by Mr. Sergius Kern of St. Petersburg.

All forgings are required to be made out of well cast ingots, from which, previous to forging, not less than 30 per cent. of the total weight of the ingot must be cut off from the head, and from the lower end not less than 3 per cent. of the original weight.

In the finished forging the area of the transverse section at the thickest part of the major length of the body must not exceed the sixth part of the original sectional area of the ingot.

Tests of Cast Iron.—A recently issued progress report has appeared * from the committee of the American Foundrymen's Association on the standardising of the testing of cast iron. The tests include: (1) Car-wheel iron; (2) stove-plate iron; (3) heavy machinery iron. Analyses are as follows:—

	I.	II.	III.
	Per Cent.	Per Cent.	Per Cent.
Total carbon	4·17	3·41	3·32
Graphite	3·43	3·08	2·99
Silicon	0·97	3·19	1·96
Manganese	0·40	0·38	0·48
Phosphorus	0·301	1·16	0·522
Sulphur	0·06	0·084	0·081

Transverse and tensile tests of various sizes of bars cast in green and in dry sand, machined and not machined, are given in tabular form.

A considerable amount of discussion has followed Kreuzpointner's paper entitled "Riddles Wrought in Iron and Steel." † It turns mainly on the questions affecting the strength of cast iron as determined by its composition and treatment, and on the problem of producing definite mixtures from various kinds of stock. Amongst the contributors are H. M. Howe, A. E. Outerbridge, W. R. Webster, and A. W. Whitney.

Testing Enamelled Ware.—C. N. Hooper ‡ gives some general notes on the testing of enamelled ware. Peeling or chipping is tested by boiling water in the vessel, and then suddenly cooling it by plunging into cold water. Crazing or cracking is looked for under a microscope. The presence of alkalies and resistance to acids is

* *Journal of the American Foundrymen's Association*, vol. ix. pp. 80–94.
† *Journal of the Franklin Institute*, vol. cl. pp. 329, 460.
‡ *Iron Age*, March 21, 1901, pp. 6–7.

tested by boiling a 10 per cent. solution of acetic acid in the ware. Lead is tested for with ammonium sulphide after the surface has been removed by strong acid. Completeness of cover is determined by soaking in a strong solution of sulphate of copper for some hours.

Armour Tests.—Particulars are given * of a test of armour-plate from the Openshaw works tested at Whale Island on February 7, 1901. The plate is 8 by 6 feet and 6 inches in thickness. It was submitted to five shots, Holtzer 6-inch projectiles weighing about 100 lbs. each being used, and the striking velocities ranged from 1974 to 2016 foot-seconds, and striking energy 2717 to 2818 foot-tons. In all cases the shot was broken up, and no really important fracture was made even by the last central shot.

Tests of Ordnance.—The recently published report of the Watertown Arsenal on the tests conducted there covers 900 pages, and contains the usual and voluminous reports on the very numerous tests made. The metal for the tubes and jackets of large guns has an elastic limit of 45,000 to 55,000 lbs., and a tensile strength of 85,000 to 95,000 lbs., with an elongation of 20 per cent. and a contraction of 40 per cent. For the barrels of small arms the elastic limit is generally above 70,000 lbs., and the tensile strength ranges from 110,000 to 120,000 lbs. A special tungsten steel, containing 1·94 per cent. of tungsten and 0·72 of carbon, had an elastic limit of 101,000 lbs. and a tensile strength of 125,500 lbs., the elongation being 19 per cent. and the reduction of area 34 per cent. Further experiments are reported on the strain set up in the manufacture of guns, and of the relief produced by annealing. More tests were also made on the effect of repeated stresses, and in one a bar of 0·82 carbon steel endured sixty-five million repetitions of 40,000 lbs. alternate tension and compression without rupture.

Nickel Steel.—The physical properties of nickel steel have been exhaustively investigated by C. E. Guillaume,† and by D. H. Browne and H. J. Porter.‡

In the course of some notes on the electro-chemical and electro-metallurgical industries in 1900, J. B. C. Kershaw § refers to the

* *Engineer*, vol. xci. p. 377.

† "Communications présentées devant le Congrès International des Méthodes d'Essai," vol. ii., 1901, Part I., pp. 181–204.

‡ *Ibid.*, pp. 205–228.

§ *Electrician*, vol. xlvi. p. 428.

increasing use of nickel in the steel industries. In 1900 the production of metallic nickel in the world is estimated at 7350 tons, mainly by metallurgical processes. Hoepfner's electrolytic process for treating the ore direct is at work at Papenburg, in Germany. At Hamilton, Ontario, the Frasch electrolytic process is to be tried. Electrolytic methods are, however, chiefly confined to treating the crude metal for refining it, being used by one firm in each of the following countries—England, Germany, Russia, and the United States. The Mond process is to be worked on a large scale at Clydach in South Wales, and at Sault Ste. Marie in Canada. Impure ferro-nickel alloys, containing 7 per cent. of nickel and some silicon, are being produced in an electric furnace direct from the Sudbury ores.

Non-Magnetic Steel.—A special steel * is used for the roofs and floors of conning towers of ironclads, which is non-magnetic, or, more properly speaking, only very feebly magnetic. The steel adopted by the Russian Navy contains—

	Per Cent.
Carbon	0·58
Chromium	1·00
Nickel	22·50

Wire Ropes.—J. Divis † discusses generally wire ropes and the wire used in their construction. The author deals with the precaution to be taken in connection with the use of wire ropes. New wire ropes stretch considerably when first put into work, and the author gives the results of experiments made to ascertain how great this elongation was. The lasting elongation when the rope was weighted to its maximum varied from 0·26 to 0·93 per cent., according to the kind of rope and numbers of wires and wire bundles. Cables elongate much more than simple ropes. The latter showed elongations of from 0·26 to 0·45 per cent., while the cables elongated permanently from 0·60 to 0·93 per cent., the dimensions of the central core having a marked influence. Wire ropes rarely break at once right across, but rather first one wire strand breaks, and then another. The testing of wire ropes is accompanied with much difficulty, in so far as gripping them fairly in the jaws of the testing machine is concerned. The tests referred to showed that the total strength of the rope was approximately identical with the sum of that of the component wires. The spiral

* Communicated by Mr. Sergius Kern.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. pp. 561-567, 578-582, 591-594.

twisting of the wire in the wire strand is almost completely without influence, and the wire strand may be looked upon as a single wire. The influence exerted by the bending of the rope around the drum is usually placed at far too high a figure, especially when the wires used are circular in section. Other points are also referred to, and the author then proceeds to a consideration of the quality of the wire used in wire rope construction. The quality depends in the first instance on that of the raw material, and then also on the way it has subsequently been treated. The question of the chemical composition is also considered. Usually each works has its own special trade secrets in connection with this point. On the Continent in judging as to the quality of a wire rope special weight is attached to its possessing bending power, while in the United Kingdom it must possess high torsion capacity. Apparently the wire is only bent in work, and is not subject to torsion at all, and thus at first sight the Continental method seems the most accurate. It is found, however, that in a worn rope the wires have lost much less of their bending power than they have of their torsion capacity, and in reality as soon as there is any marked diminution in the torsion capacity of the wires in a rope there is a chance that at any moment that rope may fracture. Especial care must be taken in the supervision of wire ropes that are not in constant use, but are only employed at intervals. Rusting is a serious danger in such cases. The rusting of wires, again, affects chiefly their torsion power, the bending power being affected to a much lesser extent. Sudden shock acts in the same way. Wires of high tensile strength are much more liable to rust than are others of lower tenacity. In conclusion the author deals briefly with some of the variations in construction introduced in recent years.

Steel Chains.—J. Seefehlner * describes the construction of steel chains for the suspension bridge over the Danube at Budapest. The distance between the axes of the chains is 65·6 feet. The links are of open-hearth steel, and all other parts of wrought iron. The longest links are 34 feet. The tensile strength of the steel was specified as 30 to 35 tons per square inch.

Steel Rails.—W. R. Webster † discusses the chemistry and heat treatment of steel rails, ascribing to the latter many of the variations

* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xliv. pp. 558-564.

† *Transactions of the American Institute of Mining Engineers*, Richmond Meeting, February 1901.

which cannot be accounted for by the composition, but admitting that a good composition is an absolute necessity. The section of the rail has a great influence on the finishing temperature, and it may be advisable to increase the amount of metal in the web and flange. A moderate amount of carbon is preferred to high carbon, as the finishing temperature may be reduced. The determination of this temperature and its uniformity is of importance. It is suggested that the shrinkage on cooling should be accurately determined and used as a check. A drop test for each blow of steel is advocated. Sufficient work must be put into the rail during rolling at a low enough temperature to break up the coarse structure and to produce the toughness desired.

The author * also refers to the recent discussion in England and America on the subject of specifications for steel rails, and adds a chronological list of the papers and discussions on the nature, composition, qualities, uses, &c., of iron and steel contained in the *Transactions of the American Institute of Mining Engineers* since 1871, with the authors' names.

P. H. Dudley, R. Trimble, E. C. Potter, G. B. Woodworth, and others contribute to the discussion on the specifications for steel rails. The first named compares the conditions in Europe and in America, and comments on some of the details, recommending somewhat closer limits for the size. Lengths of 33 feet, and even 60 feet, are now used, so that the proposed standard of 30 feet is too short.

At the October meeting in 1900 of the American section of the International Association for Testing Materials the tests for rails, fish plates, structural steel, bridge, and ship steel were considered.† As a summary of the suggestions was published by A. L. Colby ‡ in the last volume of the Institute's Journal, further details need not be given.

Steel for Spur Wheels.—J. Christie § gives the analyses of several steels used for high-speed toothed gearing:—

Carbon . . .	0·86	0·47	0·90	0·60	0·52	0·42
Manganese . .	0·51	0·66	0·64	0·64	0·55	0·73
Silicon . . .	0·27	...	...	...	0·107	0·279
Phosphorus . .	below 0·03	0·05	...	...	0·022	0·078
Sulphur . .	below 0·03	0·05	...	...	0·02	0·05

* *Transactions of the American Institute of Mining Engineers*, Richmond Meeting, February 1901.

† *Iron Age*, November 1, 1900, pp. 17-21.

‡ *Journal of the Iron and Steel Institute*, 1900, No. II. p. 215.

§ Paper read before the Engineers' Club of Philadelphia; *Iron Age*, February 28, 1901, pp. 19-24.

Cast Iron Railway Wheels.—G. W. Beebe* deals with the manufacture and testing of cast iron railway wheels, of which about $10\frac{1}{4}$ millions are supposed to be used in America at the present time. The method of carrying out the test by one of the railway companies is given in detail. The wheel is laid flange down, and a channel $1\frac{1}{8}$ inch wide is moulded rounded it in green sand, leaving the flange and tread exposed. Hot iron is poured at two points to fill the channel, and two minutes afterwards the examination is made for cracks. Two tests are allowed. In the Barr drop test the wheel is laid flange down, and should stand fifty blows from a 100-lb. tup falling 7 feet, and striking the web of the wheel. By the Master Car Builders' test the tup, weighing 140 lbs. and falling 12 feet, strikes the hub of the wheel laid flange down on three fixed supports. One line demands that it shall stand twelve blows without breaking out a piece. In the manufacture it is important to pour the iron hot and quickly, taking not more than twelve seconds for a 33-inch wheel. As soon as it has set it should be shaken out of the mould and transferred to the annealing pit.

* Paper read before the Western Railway Club, October 1900; *Engineering News*, vol. xliv. p. 266.

CHEMICAL PROPERTIES.

The Constitution of Cast Iron.—H. M. Howe * adopts the hypothesis that composition governs properties in cast iron in the same general way, and for the same reasons, as in the case of steel, *mutatis mutandis*. Carbon steel is composed of ferrite and cementite interstratified in part to form pearlite. When the combined carbon is above some point between 2 and 3 per cent. the material becomes white cast iron, so there is really an unbroken series from the mildest steel. Grey cast iron is regarded as graphite intermingled with steel or with white cast iron according as the percentage of combined carbon is low or high. In the graphiteless series the general trend of the curves of the ductility, hardness, and tenacity may roughly be plotted. In the graphitic series, when the graphite is constant the variation in the combined carbon in the matrix should produce similar results as in the graphiteless series—that is, the hardness should increase and the ductility decrease with the combined carbon, and the tenacity as a whole should attain a maximum at about 1 per cent. With constant combined carbon the strength, ductility, and hardness should decrease as the graphite increases. This reasoning is applied in the case of ordinary foundry irons containing about 4 per cent. of total carbon, and then an explanation is given of the influence of carbon on the physical properties of cast iron. Increase in combined carbon substitutes cementite for ferrite, and so increases hardness and decreases the ductility. The effect on tenacity is less easy of comprehension, but two explanations are possible, depending on the strengthening action of the hard cementite, or the hard allotropic modification of iron surrounded by the softer and more ductile ferrite. In the lower carbides the harder part is discontinuous, and accommodates itself to the flow of the ferrite; but when the carbide increases, the cementite, or whatever it may be, forms a more or less continuous skeleton, which does not yield, but is liable to the initiation of local fractures, which spread

* *Transactions of the American Institute of Mining Engineers*, Richmond Meeting, February 1901.

and produce the failure of the whole specimen under test. The strongest iron carbon compound is steel with about 1 per. cent of carbon, but in grey cast iron there is also the graphite to be considered, so that there should be a "best proportion" between the graphite and combined carbon for each percentage of total carbon to give the maximum strength. Hence the lower the total carbon the stronger should be the cast iron of "best proportion." The "best proportion" for 1 per cent. total carbon is naturally 1 of combined carbon to zero of graphite, but there are no data at present for the determination of this proportion for other carbon contents. The author is quite aware that there is much to be said against this hypothesis, but the best classes of cast iron are charcoal iron and air furnace castings, which habitually have a low carbon contents, and the loss of excellence in cupola-melted charcoal iron is not readily explicable by other causes, but is wholly in harmony with the hypothesis. This question of air furnace and cupola-melted iron is discussed at some length, and then the author turns to remarks on current opinions regarding cast iron. Removal of the silicon diminishes the graphite and increases combined carbon, thereby increasing cementite, and the resulting castings are harder and more brittle. The value and action of ferro-silicon in softening castings by increasing the graphite and in consequence the ferrite also, is thus evident. W. J. Keep infers that carbon has but little influence; but nearly all his cast irons vary but little in total carbon, in which the increase of one masks the effect of the decrease of the other constituent.

The Constitution of Pig Irons and Steels.—A. Carnot * and E. Goutal note that in recent years our knowledge as to the chemical and physical constitution of pig irons and steels has made considerable progress. The authors observe that four kinds of carbon have been admitted—graphite, graphitic temper carbon, carbide carbon, and hardening carbon. The two former are free, the third in combination with iron, and the last in solid solution, or in the form of combinations dissolved in iron, but decomposable by cold dilute acids, which the carbide carbon is not. Micrographic methods have enabled us to go still further, and one distinguishes now certain recognised components of carbon steels. These are: (1) "ferrite," or malleable iron, almost pure; (2) "sorbite," a kind of feebly carburised iron, not very definitely defined, but which is known to be attackable by cold dilute

* *Annales des Mines*, vol. xviii. pp. 263-300.

acids; (3) "perlite," composed of alternate layers of ferrite or sorbite with the carbide Fe_3C; (4) "cementite," Fe_3C occurring as lamellæ, which are readily recognised after etching; and (5) three other constituents forming the principal part of hardened steels, martensite, troostite, and austenite. So far, these last three are not very clearly defined from a chemical point of view. They contain some carbon, which dilute sulphuric acid converts into gaseous hydrocarbon, and which, when treated with cold dilute nitric acid, separates in the form of a black deposit, which dissolves rapidly, colouring the solution brown.

All kinds of iron and steel contain, however, other elements besides carbon, but of many of these we were ignorant until the authors' researches as to their mode of occurrence. It seemed to the authors that it might be possible to ascertain this by methods of chemical analysis. They have, therefore, experimented in this direction, employing solvents which would dissolve the mass of the iron, but which would leave untouched certain elements or foreign constituents, or even leave untouched a portion of these while dissolving the remainder. When thus isolated, they were submitted to further examination. The authors selected certain special metals containing some constituent in paramount quantity, the remaining foreign constituents being present in as small quantities as possible. In this way, ferro-silicons, ferro-chromes, silico-spiegeleisens, &c., were subjected to analysis. They, however, always employed commercial products, or at least products obtained from metallurgical furnaces. The high temperature of the electric furnace might give rise to combinations different from those which would result from the lower temperature of ordinary metallurgical furnaces. The authors divide their researches into two parts. The first of these relates to the ordinary elements, other than carbon, that are found in pig irons and steels. The second deals with the rarer elements, such as occur in "special" steels. The first includes silicon, sulphur, phosphorus, arsenic, and manganese; and the second, chromium, tungsten, molybdenum, titanium, copper, and nickel.

With regard to silicon, the authors first experimented with samples of ferro-silicon as low as possible in manganese. They contained about 1 per cent. of the latter element and from 10 to 14 of silicon. These were attacked by dilute hydrochloric acid, air being excluded. About 250 cubic centimetres of hydrochloric acid of 7 per cent. strength was placed in a flask, and a current of carbon dioxide passed through. The acid was boiled for a few minutes and then allowed

to cool. The stopper being removed, a few grammes of very finely powdered ferro-silicon were added, the current of carbon dioxide renewed, and the temperature raised to about 40° C., the flask being shaken from time to time. When all effervescence has ceased, the clear solution is poured away. In this a few flocculent portions of silicon hydroxide will be found. The residue is collected on a filter, washed with dilute hydrochloric acid and then with alcohol, in order to avoid oxidation. After desiccation a black powder can readily be separated by the aid of a magnet. This powder contains, in addition to a little graphite, a silicide of iron, which decomposes very rapidly under the action of alkalies, and even slowly in pure water, hydrogen being liberated. Analyses showed this silicide to have the formula FeSi.

When the same samples of ferro-silicon were submitted for a fortnight to the action of cold and very dilute sulphuric acid containing only 5 per cent. H_2SO_4, a complex residue was obtained. This consisted chiefly of carbon, various silicides, and silicon hydroxide, the latter being, doubtless, the resultant of the decomposition of other silicides. By treating this residue with hot dilute caustic potash, the FeSi and the silica were dissolved. Hydroxides of iron and manganese remained in the residue. These were dissolved with dilute sulphuric acid. The residue was washed, dried, slightly heated, and the magnetic portion withdrawn by a magnet. This magnetic residue had the composition Fe_2Si.

When silico-spiegeleisens containing 12 per cent. of silicon and 20 of manganese were treated in a similar way, double silicides of iron and manganese were found of the formula M_3Si, in which M represents the total of the two metals, iron and manganese. The presence of a considerable quantity of manganese appears therefore to exert a marked modifying influence on the composition of the silicide forms.

When some samples of ferro-manganese, in themselves not sensibly magnetic, were submitted to pulverisation, it was observed that they contained some magnetic constituents. These were analysed, and were found to be poorer in manganese but considerably richer in iron and in silicon than the original metal. About 3 per cent. of the metal could be extracted in this way. This contained from 84 to 89·8 per cent. of iron, 2·9 to 9·45 per cent. of manganese, and 3·95 to 6·50 per cent. of silicon. These portions were subjected to the action of very dilute acids, and were found to leave a residue which was nothing else than the iron silicide previously observed, Fe_2Si.

One may therefore conclude that ferro-silicons contain two combinations of iron with silicon, FeSi and Fe_2Si. They may also, when rich enough in manganese, as silico-spiegels, contain a silicide of the formula M_2Si, in which there may be a considerable percentage of manganese. The silicide Fe_2Si was first prepared by Hahn; Moissan obtained it in the electric furnace, and Lebeau has quite recently isolated it from ferro-silicons containing 10 to 20 per cent. of silicon prepared in the electric furnace. The silicide FeSi had been obtained by Frémy and by Hahn, and has also, since the authors' investigations, been prepared by Lebeau in the electric furnace, but in the presence of silicide of copper, which may have had the effect of lowering the temperature of the reaction and of causing it to approach that of ordinary metallurgical furnaces. It is to be observed, however, that the properties of these two silicides, prepared as above stated, are not altogether identical; for those obtained in the electric furnace are not attacked by acids, while those produced under ordinary metallurgical conditions are readily attacked by hot acids, even when dilute. The authors have endeavoured to isolate these two silicides from ordinary pig irons, but have not been successful. They are led to believe that the cooling produces the decomposition of the silicide FeSi, or that this silicide forms with the mass of the iron a solid solution or homogeneous mixture. The absence of a free silicide of iron appears equally well established by experiments of H. Le Chatelier on the electric resistance of steels. These showed that the resistance increased proportionately with the quantity of silicon, and one must admit therefore that this element is present in steel in the state of a homogeneous mixture, or of a solid solution. On the other hand, the residue left by ordinary cast irons after they have been attacked by dilute sulphuric acid out of contact with the air, has shown that a small quantity of silicide of manganese is present. This the authors consider to have the formula MnSi. They have not, however, been able to obtain it in a pure state, as it was always mixed with an excess of carbide of iron.

The next element the authors deal with is sulphur. To isolate the sulphides from iron or steel, it is not possible to utilise the same method as that employed in connection with the silicides, as hydrogen sulphide would be evolved. When, however, the attacking agent is the neutral chloride of copper and potassium, the whole of the sulphur remains in the insoluble residue. This residue sometimes contains sulphide of iron, but the authors have more frequently found

it composed to a large extent of the sulphide of copper, CuS. The authors find that the sulphide of iron is not attacked by the copper-potassium chloride, and they have ascertained the existence in pig irons of the compounds FeS and MnS. The authors think that when manganese is present this sulphide forms in preference to that of iron. The copper chloride, however, seems to decompose it, leaving copper in place of the manganese. In the case of a hardened steel containing—

Carbon.	Manganese.	Sulphur.
0·17	0·65	0·18

almost the whole of the sulphur was found in the residue combined with copper as CuS. Hardening, therefore, does not affect the mode of existence of sulphur in steels in the presence of manganese.

Dealing next with phosphorus, the authors found that when they used the perfectly neutral double chloride of copper and potassium, the phosphorus remained entirely in the residue in the form of phosphide of iron, sometimes mixed with a very small quantity of phosphide of manganese, as well as silica, carbon, and copper sulphide. Iron phosphide is so feebly magnetic that complete separation by a magnet is not possible, and the authors have been obliged to check its formula by comparing the results of a large number of analyses of the residues from highly phosphoric pig iron and steels. To do this the residue was attacked by brominated nitric acid, and the filtered solution divided into two parts, the iron precipitated in one by ammonia, redissolved, reduced, and liberated by permanganate, and in the other the phosphoric acid precipitated by molybdate, after destroying organic matter by the aid of chromic acid.

The authors conclude that the phosphide of iron which occurs in pig irons and steels has the formula Fe_3P. This is the formula that has long been accepted. They have experimented to see whether the same phosphide occurs in steels that have been rapidly hardened. The steels selected contained—

Carbon.	Manganese.	Phosphorus.
0·35	1·48	0·37

The residue from 10 grammes of this steel contains 33·2 milligrammes of phosphorus and 165 milligrammes of iron without a trace of manganese. Hardening in the presence of manganese, therefore, exerts no influence on the way the iron and phosphorus combine.

The next element considered is arsenic. Dilute hydrochloric acid leaves it all in the residue if air be excluded. The authors found in a

steel an arsenide of the formula Fe_2As. Arsenic, however, does not appear to enter into combination with iron, if it has been slowly annealed, but remains in irons and steels so treated simply dissolved. In hardened steel the case is different. Here an arsenide is produced when copper was present; an arsenide was left that had the formula M_3As_2, and from another steel containing no copper but 4·25 per cent. of arsenic the authors obtained, after hardening from temperatures of 400° and 1000° C., an arsenide of the formula Fe_2As. Thus, while annealed steel only contains non-combined arsenic, the hardened metal contains an arsenide. Arsenic, therefore, behaves in metallurgical products like carbon. Hardening causes it to form definite compounds, and slow annealing causes it to assume its free state again. This difference in the behaviour of arsenic and phosphorus accounts for the long-noticed fact that equal percentages of these two elements act in such very different ways.

The next element passed in review is manganese. Here the attacking agent used was a solution of ammonium acetate rendered slightly ammoniacal and raised to a boiling temperature. By this means the authors isolated a compound having the formula Fe_3C, $4Mn_3C$. This corresponds to 74 per cent. of manganese. This was obtained from alloys containing 79 per cent. and 84 per cent. of manganese, and is of much interest in that boiling water attacks or does not attack ferro-manganese according to whether the manganese present exceeds or falls below 74 per cent. When ferro-manganeses containing from 74 down to 60 per cent. of manganese are treated with very dilute cold acetic acid, they give as residue a crystallised non-magnetic double carbide of the formula Fe_3C, $2Mn_3C$. If the percentage of manganese varies between 60 and 30 per cent., the residue contains a mixture of two double carbides, one of which has just been mentioned and another non-magnetic carbide of the formula $2Fe_3C$, Mn_3C. This double carbide appears to have a tendency to separate out during the cooling down of ingots of ferro-manganese, as the authors show. Metallurgical products with 30 per cent. down to 18 per cent. of manganese cannot be attacked by acetic acid, the action of which is too feeble. Sulphuric acid, even, when cold and dilute, is, on the other hand, too energetic in its action, only leaving as an insoluble residue a small quantity of silicide and carbide of iron. In this series of metals the authors consider the carbide $2Fe_3C$, Mn_3C to exist. Finally, for percentages of manganese below 18, the free carbide Fe_3C rapidly separates under the action of very dilute cold

sulphuric acid. The authors think that the double carbide lowest in manganese, which exists in pig irons, contains 18 per cent. of manganese. This double carbide would have the formula $4Fe_3C, Mn_3C$. It exists in the samples with less than 18 per cent. of manganese.

The authors then summarise their conclusions, pointing out that in pig irons and steel (1) sulphur is usually combined nearly entirely with manganese as MnS, the excess, if any, being present as FeS; (2) phosphorus is combined directly with iron as Fe_3P; (3) arsenic is almost always free, or exists as a solid solution, but after hardening it is partially combined with iron as Fe_2As; (4) silicon is usually in the free state in cast irons. It can also unite with iron and manganese to form MnSi and FeSi, but the latter is dissociated on slow cooling, or at least cannot then be isolated. The silicide MnSi is not dissassociated by cooling. Ferro-silicons contain both FeSi and Fe_2Si. Silico-spiegeleisen contains a double silicide, M_3Si; (5) carbon is combined with both iron and manganese. It forms in ferro-manganese double carbides, of which the authors have recognised four: $Fe_3C, 4Mn_3C$; $Fe_3C, 2Mn_3C$; $2Fe_3C, Mn_3C$; and $4Fe_3C, Mn_3C$. It is this latter which appears to exist in spiegeleisens and pig irons; (6) the excess of carbon exists in combination with iron as Fe_3C.

Taking the following ordinary analysis of a pig iron:—

	Per Cent.
Iron	94·00
Silicon	0·63
Phosphorus	0·15
Arsenic	0·05
Sulphur	0·12
Manganese	2·00
Combined carbon	2·45
Graphite	0·60
Total	100·00

the results of the authors' investigations would lead them to state the analysis in the following terms:—

	Per Cent.
Manganese sulphide, MnS	0·33
Iron phosphide, Fe_3P	0·96
Manganese silicide, MnSi	0·62
Carbide of iron and manganese, $4Fe_3C, Mn_3C$	7·48
Carbide of iron	24·70
Carbon as an indefinite sub-carbide	0·32
Carbon as graphite	0·60
Silicon, non-combined	0·42
Arsenic, free	0·05
Iron, free or as indefinite hydride or carbide	64·52
Total	100·00

The authors next deal with the elements more rarely found in steels. In two ferro-chromes containing—

	I. Per Cent.	II. Per Cent.
Chromium	57·6	59·1
Iron	32·6	32·3
Carbon	9·9	9·1

the authors found a carbide of the formula $Fe_3Cr_9C_7$, or Fe_3C, $3Cr_3C_2$. Fe_3C is cementite, and Cr_3C_2 is the formula given by Moissan for the chromium carbide obtained by him in the electric furnace. Steels low in chromium gave as residue $3Fe_3C$, Cr_3C_2. A sample of ferro-manganese containing a little chromium gave this same residue. It is interesting, the authors add, to note that the double carbides of chromium and iron are like those of manganese and iron series in which the chromium varies with the percentage that existed in the mother metal.

In tungsten steels the authors have found Fe_3W, and Fe_3C, WC. This latter was in steel containing 6·1 per cent. of tungsten and 2 per cent. of carbon.

With regard to molybdenum, the authors have observed the presence of Fe_3Mo_2, and Fe_3C, Mo_2C.

Titanium does not seem to be in a state of combination in ferro-titanium, nor in the case of copper; most of this forms no definite alloy with iron in products low in copper, whether hardened or annealed. An extremely small residue obtained in one instance was non-magnetic, and contained both iron and carbon. The authors suggest that this may have been either an alloy or a carbide.

As to nickel, the authors were unable to obtain any results. The nickel always went into solution simultaneously with the iron. The authors think that the nickel exists in the free state.

In conclusion, the authors add a note on the analysis of ferro-manganese. Copper chloride is useless for the determination of carbon in alloys with more than 80 per cent. of manganese. Direct combustion of the fine powder in a current of oxygen gives the best results.

The Solution of Iron in Hydrochloric Acid.—J. T. Conroy* has experimented upon the rate of solution of iron in hydrochloric acid, a matter which has an important bearing on the process of

* *Journal of the Society of Chemical Industry*, vol. xx. pp. 316-320.

pickling in acids. Under certain conditions, it is found that with the concentration of the acid the rate of solution increases in a geometrical progression over a considerable range. The rate is doubled for each increase of 30 grammes of acid per litre. A similar law connects the activity and the increase of temperature. Between 25 and 216 grammes of acid per litre, the rate appears to be doubled for each rise of 10° C. The results are plotted as curves which are logarithmic in form, and calculations based on these curves as to the relative times taken for cleaning plates agree very well with the results obtained on a practical scale.

The Passive State of Iron.—Hittorf * gives the results of his extensive experiments on the nature of the passive state of metals, especially of iron and steel, which is caused by dipping them into concentrated nitric acid.

Corrosion of Iron and Steel.—W. Wark † discusses the durability of wrought iron pipes. After the lapse of eleven years wrought iron pipes employed in the distribution of coal-gas at a town in New South Wales had completely perished. The decay is thought to have been caused by the light character of the soil and the frequent street watering.

The full text of H. M. Howe's report ‡ on the relative effects of corrosion on iron, mild steel, and nickel steel in air, sea-water, and ordinary water has been published.

Oxide Film on Annealed Sheets.—H. Kamps § considers the question of the film of oxide that occurs on annealed sheets. Sheets that have cooled after passing through the rolls are coated with an easily detachable film, which consists of ferric oxide and ferrous oxide in varying proportions. It is feebly magnetic. For many purposes it is necessary that this scale should be removed, but for others it is not so necessary. All sheets, whether scaled or not, are annealed in closed boxes, either to get rid of any acid that may still adhere and to ensure softness, or to attain the highest limit of magnetic perfection.

* Paper read before the German Electro-Chemical Society.

† *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxliii. pp. 259–261.

‡ "Communications présentées devant le Congrès International des Méthodes d'Essai," vol. ii. Part I. 1901, pp. 229–266. See *Journal of the Iron and Steel Institute*, 1900, No. II. p. 567.

§ *Stahl und Eisen*, vol. xxi. pp. 224–227.

It is not, however, practicable to keep air entirely away from the sheets during this process, and consequently all annealed sheets show oxidised edges. This film is not sharply defined from the iron, but the oxide can be seen passing gradually into the iron. To remove this film only polishing is possible, acid treatment being now impracticable. Only ferrous oxide is readily removed by acid, the ferric oxide showing itself intractable. It is necessary for magnetic purposes to ascertain the thickness of this oxide film, and the author shows how this may be calculated. The maximum thickness observed by him in tests referred to was 0·097 millimetre. It consists mainly of ferric oxide. Its thickness is variable, and sometimes so considerable that it cannot be considered as capable of being disregarded, as is so frequently the case. It is not possible, either, to assume any average thickness. It is the very thinnest form of sheet, too, that is of importance in electro-technology, and the author's results show clearly that it is impossible to compare directly results obtained for pure iron with others from sheets still covered with this film. The author deals further with this point.

The Rusting of Tinned Iron.—F. Ulzer's * experiments confirm the general view that tinned iron goods rust owing to the presence of minute crevices in the surface of the iron plate, which are not effectually sealed by the molten tin in the process of dipping. Oxidation begins at these points, and extends under the tin coating, causing it to separate.

Iron Silicide.—P. Lebeau † has prepared, by the action of silicide of copper on an excess of iron, the crystallised silicide of iron, $SiFe_2$. This compound is but little altered by acids and alkalies, with the exception of hydrochloric acid, concentrated or dilute, which dissolves it completely. It can be isolated from the ferro-silicons used in ironworks containing 10 to 20 per cent. of silicon, and communicates its properties to them, products containing more than 15 per cent. of silicon being attacked only with difficulty by nitric acid if they have not been finely pulverised.

Copper in Iron and Steel.—J. E. Stead ‡ reviews the statements and researches of various authorities on the presence and effect of

* *Mittheilungen des k.k. Techn. Gewerbe-Museums in Wien*, vol. x. p. 203; *Journal of the Society of Chemical Industry*, vol. xx. pp. 127.

† *Comptes Rendus de l'Academie des Sciences*, vol. cxxxi. pp. 583-586.

‡ *Journal of the West of Scotland Iron and Steel Institute*, vol. viii. pp. 4–16. See also the author's paper in this volume.

copper in iron and steel. Very extreme views are expressed on the possibility of alloying these metals, and there is a field for further research in this direction. The evidence is overwhelming that copper to the extent of at least 0·3 per cent., and even much more when the sulphur is low, does not produce red-shortness. Apparently more than 0·4 per cent. tends to prevent perfect welding, but smaller quantities are not detrimental. Finally, the influence of copper on the mechanical properties of steel in the cold state is certainly beneficial within certain limits, and much has been done on this and on other points by A. L. Colby, of whose work a summary is given. A bibliography containing twenty-eight items is appended.

F. H. Williams * has experimented on the effect of copper in reducing the corrosion of soft Bessemer steel and wrought iron. The samples were frequently dipped into water and allowed to dry in the air for a month, after which they were cleaned and weighed. With an increasing percentage of copper the loss showed a decrease, as was the case with the nickel steel tested by H. M. Howe.†

Vanadium in Steel.—An article on vanadium has been published by J. Baxeres.‡ The metal was discovered by Del Rio in a lead ore from Zimapan, Mexico, in 1801, and named by him erythronium. It was subsequently discovered by Sefström in 1830 in an iron slag from the Taberg, in Sweden, and named vanadium. In the metallurgy of iron its employment is of great importance. The presence of 0·5 per cent. of vanadium in mild steel doubles its tensile strength.

Elimination of Steel Particles from other Metals.—Bornhauser § eliminates fragments of steel from brass or other metals by dipping the material in a warm or boiling solution of one part of alum in four or five parts of water. The steel dissolves rapidly and passes completely into solution.

* *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xvi. pp. 231–233.

† *Journal of the Iron and Steel Institute*, 1900, No. II. p. 567.

‡ *Revista Minera*, vol. lii. pp. 1–2.

§ *Mechanische Zeitung; Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlix. p. 87.

CHEMICAL ANALYSIS.

CONTENTS.

I.—*ANALYSIS OF IRON AND STEEL.*

Iron and Steel Analysis.—Select methods for the analysis of iron and steel are described in an exhaustive German work by A. Classen.* The methods described are not exclusively of German origin, detailed descriptions being given of methods devised by Abel, Atkinson, Arnold, Bailey, Baker, Blount, Crookes, Galbraith, Hogg, M'Millan, Rideal, Roscoe, Saniter, Stead, Thorpe, Turner, Warren, and Young. Of the 940 pages covered by the volume, 118 are devoted to iron and steel.

A general account of the chemical and physical laboratories of the Case Threshing-Machine Company has appeared,† with two illustrations of the interior.

Determination of Carbon.—R. Job and C. T. Davies ‡ publish a modification of Sargent's recently described process,§ with continuous heating arrangement, in a simplified form. A combustion requires 19½ minutes, for the first seven of which oxygen, and for the remaining time air is used. Without cooling the furnace, a second boat is then introduced, and another combustion effected with fresh potash bulbs, and so forth. A full description of the arrangement and of the method of use is given.

* *Ausgewählte Methoden der analytischen Chemie*, Brunswick, 1901.
† *Iron Age*, January 24, 1901, pp. 4-6.
‡ *Journal of the American Chemical Society*, vol. xxii. pp. 791-797.
§ *Journal of the Iron and Steel Institute*, 1900, No. II. p. 574.

G. W. Sargent * finds that the solution of potassium copper chloride may be used several times over for the determination of carbon in iron if chlorine is passed through it to reoxidise it. When the iron accumulates in the solution to too great an extent, it must be thrown away.

H. Goeckel † has designed a flask for use in the determination of carbon in iron. The apparatus differs from the previous one of the same character by having a wider ground neck, into which fits the condenser, through which passes a thistle funnel tube reaching to the bottom of the flask. The top of the neck of the flask is expanded, so that it can be filled with water to seal the apparatus after introducing the condenser. The side tube of the flask is placed somewhat higher than before. The acid mixture is poured through the funnel tube, which is then sealed by means of a glass rod. At the lower end of the condenser is fitted a small slightly bent hook supporting a little glass bucket containing the sample. By a slight jerk this is made to drop into the acid.

In the estimation of carbon in ferrochrome, A. A. Blair ‡ places 25 grammes of pure potassium hydrogen sulphate in a platinum boat and fuses it over a bunsen burner to destroy any carbonaceous matter. When cold one gramme of the finely powdered sample is sprinkled over it, and the boat is inserted into a larger one, which is then fitted with a cover so arranged that any particles spirted up from the melting mass run into the larger boat. By this means the combustion tube is kept clean. The plugs are made of pumice wrapped with platinum foil, and are pushed in after the boat. The use of india-rubber stoppers is entirely avoided.

The combustion is made in a slow current of purified oxygen, the bulk of the liberated sulphuric acid condenses in the tube containing the beads, and the gases are then passed through two glass flasks kept hot, and containing a solution of chromic acid in sulphuric acid to retain any sulphur dioxide. After passing over pumice-stone saturated with chromic acid and over calcium chloride, the carbon dioxide is finally absorbed in the usual manner and weighed. The guard tube of the absorption apparatus is connected with a gasometer, which acts as an aspirator and relieves the pressure in the apparatus, which other-

* *Journal of the American Chemical Society*, vol. xxii. p. 210.

† *Zeitschrift für Angewandte Chemie*, 1900, p. 1034.

‡ *Journal of the American Chemical Society*, vol. xxii. pp. 719-723; *Journal of the Chemical Society*, vol. lxxx. pp. 74-75.

wise might become excessive owing to the condensation of sulphuric acid in the bent tube.

Determination of Phosphorus.—V. Meurer * describes the centrifugal apparatus manufactured by Peters and Rost of Berlin, and its application to the determination of phosphorus. The Braun centrifugal apparatus now so commonly used in the separation of the molybdate precipitate enables fourteen samples to be treated simultaneously, and is very useful where many determinations have to be made at the same time. This advantage, however, ceases when it is only a question of a single analysis, the apparatus being cumbersome. The other apparatus now illustrated and described by the author is very simple, and can be screwed on to any table and set in motion by hand. It has given much satisfaction in the laboratory of the Burbacher Works.

Determination of Manganese.—H. Jervis † finds that the process in which manganese is oxidised to permanganate by the oxides of lead is not always accurate.

Determination of Silicon.—A number of letters have been published ‡ on the question of the time taken for the determination of silicon in iron. The time given varies from twelve minutes upwards for a single test. In one case a minimum of 6½ minutes is given.

The use of the electric furnace has led to the manufacture of "metallic" silicon and silicon alloys. B. Neumann § points out that it is proposed to use the silicon "metal" as made in steelwork practice as a substitute for aluminium and as a direct addition to the ladle for certain special kinds of steel. The analysis is not easy, in that the silicon is not soluble in ordinary hot acids, but only in a mixture of nitric acid and hydrofluoric acid, or in hot concentrated solutions of potash or soda. The best method is to place 100 cubic centimetres of a 10 per cent. solution of hot caustic soda in a silver dish, and then to charge in little by little one gramme of the very finely powdered silicon. The whole is then heated on the water-bath until an evolution of hydrogen can no longer be detected. After dilution the residue is filtered off and well washed. This residue contains

* *Stahl und Eisen*, vol. xxi. p. 128 ; one illustration.

† *Chemical News*, vol. lxxxi. pp. 171-172.

‡ *Iron Trade Review*, March 7, 1901, p. 10 ; March 21, p. 11.

§ *Chemiker Zeitung*, vol. xxiv. pp. 869-870, 888-889.

hydroxides of iron and aluminium (some of the alumina passing into the filtrate) together with lime, ferro-silicon, free silica, and silicon carbide. This residue is first extracted with hot hydrochloric acid to free it from iron, alumina, and lime, then with nitro-hydrochloric acid to decompose the ferro-silicon present; the difference in weight is determined, and the silica determined by evaporating with hydrofluoric acid. The residual silicon carbide can thus also be determined. The silica in the filtrate is determined much in the usual way. Of nine samples of metallic silicon produced in the electric furnace, six contained from 93·83 to 97·52 per cent. of silicon, 0·10 to 1·04 per cent. of iron, 0·0 to 0·53 per cent. of aluminium, 0·18 to 0·37 per cent. of calcium, and an undissolved residue of ferro-silicon, silica, and silicon carbide, amounting to from 1·95 to 4·63 per cent. The other three samples were very impure. One contained 80·85 per cent. of silicon, and another as little as 70·67 per cent. The undissolved residue varied from 17·12 to 23·75 per cent. Of this 10·82 to 16·40 per cent. was carbide. These examples show that such commercial silicon may be distinctly impure. The specific gravity enables some check on this to be obtained, as the specific gravities of the six best samples varied from 2·26 to 2·32, while those of the impure samples were higher, ranging up to 2·70.

Determination of Nickel.—A rapid volumetric method for the determination of nickel in steel is given.* It depends on the formation of a double cyanide of nickel and potassium when potassium cyanide is added to an alkaline solution of a nickel salt. The excess of the reagent is determined by the solution of iodide of silver suspended in the solution.

Analysis of Ferro-Silicons.—F. Ibbotson and H. Brearley † state that ferro-silicon and silico-spiegel not being amenable to treatment with copper solutions, the total carbon is estimated by combustion in a current of oxygen; the graphite by treating 2 to 3 grammes with 70 to 100 cubic centimetres of nitric acid of specific gravity 1·2, exciting and gently maintaining the action by adding a few drops of hydrofluoric acid; the graphite is collected and washed successively with water, boiling sodium hydroxide, dilute hydrochloric acid, and again with water, and ultimately burnt with oxygen. Silicon is

* *Iron and Coal Trades Review*, vol. lxi. pp. 1158-1159.
† *Chemical News*, vol. lxxxii. pp. 269-270.

estimated by boiling 2 grammes of the finely-powdered alloy, until decomposition is complete, with 50 cubic centimetres of concentrated hydrochloric acid and 10 to 20 cubic centimetres of nitric acid, adding twice the volume of water, filtering at once, washing with dilute hydrochloric acid, igniting and weighing, a correction of 0·1 per cent. for soluble silica being made. Manganese is estimated by dissolving 1 gramme in 30 cubic centimetres of nitric acid of specific gravity 1·2 and 1 or 2 cubic centimetres of hydrofluoric acid, cooling, adding 10 cubic centimetres of water, then about 2 grammes of sodium bismuthate, filtering, adding standard hydrogen peroxide, and titrating with $N/10$ permanganate. With silico-spiegels, the solution of the alloy is made up to 100 cubic centimetres, and 25 cubic centimetres are treated with nitric acid, &c. The phosphorus is estimated by treating 2 grammes of the finely powdered alloy with 45 cubic centimetres of nitric acid of specific gravity 1·2 and 25 to 30 drops of hydrofluoric acid, the latter treatment being once repeated when action first subsides; when decomposition is complete, permanganate is added until manganese dioxide is precipitated and then ferrous sulphate to clear the solution, which is filtered, treated with 6 to 7 cubic centimetres of ammonia, precipitated with ammonium molybdate, and the lead molybdate weighed; any phosphorus in the hydrofluoric acid must be allowed for.

Analysis of Tungsten and Chrome Steel.—McKenna's process * for the estimation of tungsten and chromium in steels is criticised by Otto Herting.† The author gives a new process for the estimation of the tungsten. One to three grammes of the ferro-tungsten are treated with nitro-hydrochloric acid and evaporated twice with nitric acid on the water-bath. The mass is dried at 120° and then dissolved in dilute nitric acid; then insoluble matter, consisting of tungsten trioxide, silica, and a little ferric oxide, is fused with sodium carbonate and the fused mass treated with water, when a residue of ferric oxide is left, which should be tested for traces of silica. The filtrate is evaporated twice with nitric acid, and the residue treated with dilute nitric acid, which leaves the silica and tungsten trioxide undissolved. These are collected and weighed, and then fused with five times their weight of potassium hydrogen sulphate; the fused

* *Journal of the Iron and Steel Institute*, 1900, No. II. p. 580.

† *Zeitschrift für Angewandte Chemie*, 1901, pp. 165-166; *Journal of the Chemical Society*, vol. lxxx. pp. 284-285.

mass is digested with a cold solution of ammonium carbonate, which dissolves the tungsten trioxide and leaves the silica undissolved; the latter is weighed and the former obtained by the difference. The tungsten may also be estimated volumetrically by suspending a well-washed moist precipitate of silica and tungsten trioxide in hot water and titrating with normal sodium hydroxide, using phenolphthalein as indicator. One cubic centimetre of the solution = 0·092 gramme of tungsten.

According to F. Ibbotson and H. Brearley * manganese is estimated in tungsten powder and alloys by treating 1 gramme with 10 cubic centimetres of hydrofluoric acid and 4 cubic centimetres of nitric acid, adding, when action slackens, 2 or 3 cubic centimetres of sulphuric acid, then oxidising and titrating in the usual way. As a rule, these alloys and powders contain less than a half per cent. of manganese; in the case of alloys sometimes met with, containing 10 per cent. of manganese, not more than 0·1 gramme should be used.

In the estimation of chromium in alloys of iron, chromium, tungsten, and manganese, the alloy is digested with a mixture of sulphuric and hydrofluoric acids, treated with a few grammes of solid permanganate, then diluted and boiled with excess of permanganate until solution is complete. Or it may be dissolved in nitro-hydrofluoric acid, boiled with sulphuric acid until sulphur trioxide is evolved, and then be diluted for further treatment.

According to F. Ibbotson and H. Brearley,† five grammes of the steel or alloy are digested below the boiling-point in 100 cubic centimetres of strong hydrochloric acid, with nitric acid in quantity only slightly above that required to keep the iron in the ferric state; the solution is boiled until the tungsten trioxide commences to separate; it is then diluted with at least twice its volume of water and boiled. The precipitate of tungsten trioxide, silica, and a little iron is further treated. When ferro-tungstens are treated in this way, the tungsten remaining in solution must be recovered by evaporation and included. With nickel-tungstens, hydrofluoric and nitric acids are required, the latter being ultimately expelled by boiling with sulphuric acid; the solution is then diluted and filtered, and the tungsten trioxide weighed whilst the nickel is estimated cyanometrically. If silica and molybdenum are also to be determined in the nickel-tungstens, hydrochloric and

* *Chemical News*, vol. lxxxii. pp. 209–210.
† *Ibid.*, vol. lxxxii. pp. 224–225.

not hydrofluoric acid is used. Tungsten molybdenum steels are treated in quantities of from 2 to 3 grammes with hydrochloric and nitric acids, evaporated to pastiness, boiled with dilute hydrochloric acid, the tungsten trioxide weighed, and the molybdenum estimated as lead molybdate.

In addition to the ordinary constituents in tungsten powders, a substance in the form of bronze to brown cubes or tetrahedra, of a specific gravity of 7·3, has been isolated by sifting through a 60-mesh sieve, boiling a portion with sodium hydroxide, washing, drying, digesting with nitro-hydrofluoric acid, and washing and boiling the residue with sodium hydroxide.

E. Bagley and H. Brearley * state that in working by Schöffel's method, the residue is liable to contain a variety of substances which are largely eliminated by using the following modification. Five grammes of the sample are digested at the boiling-point, and occasionally shaken with 50 grammes of crystals of cuprammonium chloride, 100 cubic centimetres of water, and 50 cubic centimetres of strong hydrochloric acid. A little while after the precipitated copper has dissolved, the solution is filtered and the residue washed with dilute hydrochloric acid, ignited, silica volatilised by treatment with hydrofluoric acid, the residue fused with sodium carbonate, dissolved in water, and the ferric oxide ignited, &c. The filtrate, if yellow, is acidified with sulphuric acid, treated with ferrous sulphate, titrated with permanganate, and calculated into chromic oxide; this, together with the ferric oxide, is deducted in order to obtain the percentage of tungsten. With less than 1 per cent. of tungsten, only 10 per cent. of hydrochloric acid should be used in the cuprammonium solution, otherwise the results obtained may be low. Molybdenum, if present, may or may not pass into solution; part of the silicon also is dissolved; silicon cannot therefore be estimated by the loss on treatment with hydrofluoric acid.

II.—*ANALYSIS OF IRON ORES AND SLAG.*

Determination of Iron.—Hillebrand † and Stokes have investigated the relative values of the Mitscherlisch and the hydrofluoric acid methods of determining ferrous iron in minerals. The former

* *Chemical News*, vol. lxxxii. pp. 270-271.

† *Journal of the American Chemical Society*, vol. xxii. p. 625.

process, in which the material is decomposed by sulphuric acid in a closed vessel, is rendered untrustworthy by the reducing action of the sulphides present on the ferric salts produced.

According to J. W. Richards,* a specific gravity test of such ores, which are simply mixtures of magnetite and quartz, may be as accurate as an analysis. Samples weighing from 1 to 50 lbs. should be tested, according to the kind of balance available. The results should be accurate to 0·1, and may be so from 0·02 to 0·03 per cent., which is equivalent to a maximum error of 1 to 3 per cent. on the iron contents. A table is given showing the percentage of magnetic oxide (or iron) and silica in magnetite, with the corresponding specific gravity of the sample.

Determination of Phosphorus.—In the estimation of phosphorus in ores containing arsenic by a method proposed by J. M. Camp,† five grammes of pulverised dry ore are gently boiled for thirty minutes with hydrochloric acid, the solution diluted, filtered, and exposed on a steam-bath overnight. In the morning, two grammes of pure oxalic acid and 50 cubic centimetres of hydrochloric acid are added, the solution covered with a watch-glass, taken to dryness sharply, but not baked, then, when cool, evaporated with 30 cubic centimetres of strong hydrochloric acid until the first appearance of insoluble ferric chloride, treated with 10 cubic centimetres of strong nitric acid, and when violent action has ceased, warmed to complete solution, diluted, and filtered into a flask, washing with 2 per cent. nitric acid. The portion of the ore insoluble in hydrochloric acid is ignited, fused with mixed carbonates, dissolved in excess of hydrochloric acid allowed to dry overnight in a steam-bath, moistened with dilute hydrochloric acid and enough hot water to dissolve chlorides, warmed, filtered, added to the contents of the other flask, and the phosphorus determined in the whole, in the manner described. The method is applicable to the analysis of pig iron and steel.

Determination of Alumina.—According to J. M. Camp, ‡ a gramme of the ore or cinder is treated for silica, and the cold hydrochloric acid filtrate is diluted to about 400 cubic centimetres and treated with 30 cubic centimetres of a 10 per cent. solution of ammonium phos-

* *Journal of the American Chemical Society*, vol. xxii. pp. 797–798.
† *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xvi. pp. 55–58.
‡ *Ibid.*, pp. 59–60.

phate, and then with ammonia until a faint precipitate forms; 15 cubic centimetres of strong hydrochloric acid are added, and for ores 50 cubic centimetres, for cinder 30 cubic centimetres of a 20 per cent. solution of sodium thiosulphate. The mixture is heated to boiling, 8 cubic centimetres of strong acetic acid and 15 cubic centimetres of 20 per cent. solution of ammonium acetate are added, and the whole boiled for ten minutes, allowed to subside, the clear solution decanted, precipitated, filtered, and washed on the filter with hot water ten times, but not more, as aluminium phosphate is slightly soluble. The precipitate is ignited in a platinum crucible in front of the muffle until the paper chars, then finished in the hottest part; 41·85 per cent. of the weight is alumina.

Determination of Tungsten.—F. Bullnheimer * observes that the analysis of tungsten ores presents considerable difficulties. It is better to fuse them with sodium peroxide than with soda and nitre, or than it is to treat them with nitro-hydrochloric acid. The method he adopts is as follows:—From 1 to 2 grammes of the finely powdered ore is mixed in a nickel crucible with 4 grammes of sodium peroxide; about 3 grammes of caustic soda is added in lump form, passing it right through the mixture until it touches the bottom of the crucible. The whole is then heated gently until it has softened, and then, stirring constantly, with the full flame of the burner, until it has become thin fluid. Any tin-stone present remains undissolved, while wolfram is completely decomposed. The crucible, while still hot, is placed in a beaker containing some water, and the solution subsequently brought into a 250 cubic centimetre flask. If it is coloured green by manganate, it should be decolorised by the use of hydrogen peroxide. Any deposit is filtered off, and to one-half of the solution 20 grammes of ammonium nitrate is added. Silica and stannic acid, if present, are allowed to separate by settling, and then magnesium nitrate is added in small quantities for the precipitation of arsenic and phosphoric acids. After standing for six to twelve hours the precipitate is filtered off, washed with ammonia, and then with water. If the silica and stannic acid are not allowed to settle out before the magnesia addition, the precipitate produced will be found to contain tungsten. The ammoniacal solution is made feebly acid with nitric acid, and when cold there is added to it from 20 to 30 cubic centimetres of a solution made by dissolving 200 grammes of mercury

* *Chemiker Zeitung*, vol. xxiv. p. 870.

nitrate in 980 cubic centimetres of water and 20 of concentrated nitric acid. Some hours are allowed to elapse, and then the free acid present is nearly neutralised with ammonia. The whole is then allowed to settle, after which it is filtered, washed with water containing mercury nitrate, and subsequently with water. The filter is then allowed to dry, and is afterwards burnt. The residue is ignited strongly until the weight is constant. If much molybdenum is present this latter operation may take somewhat long. It is more rapidly effected if after the first strong ignition some ammonium chloride is added to the mixture.

Analysis of Titaniferous Iron Ores.—J. H. L. Vogt* describes the method for the determination of titanic acid in iron ores which is in use at the Metallurgical Laboratory at Christiania. The ore is first treated with hydrochloric acid, and the undissolved residue fused with sodium-potassium carbonate. The silica is determined as usual by evaporation with hydrochloric acid, but as it always contains some titanic acid, it is treated, after being weighed, with hydrofluoric and sulphuric acids.

In the complete analysis ammonia and bromine are used to effect a precipitate, and this is then ignited at a low temperature, and the weight of the mixed Fe_2O_3, Al_2O_3, Mn_3O_4, P_2O_5, and TiO_2 then ascertained. These substances are dissolved with hot concentrated hydrochloric acid, and that portion of the titanic acid obtained from the silica is brought into solution by fusion with potassium hydrogen sulphate. The solution containing these substances is then exactly neutralised, and a few drops of sulphuric or hydrochloric acid added in excess. The ferric salt present is reduced by sulphurous acid, and the solution is then largely diluted and boiled for at least an hour. An impure titanic acid settles out. This contains alumina, phosphoric acid, and some ferric oxide. It is filtered through a double filter, and treated in the same way as before. The residue is then fused with pure soda for a considerable time before the blowpipe, when alumina and phosphoric acid are converted into soluble sodium salts, while the titanic acid forms a sodium titanate insoluble in cold water. This is filtered off, washed with cold water, dissolved in hydrochloric acid, and after neutralising and adding sulphurous acid, is precipitated in the manner above described. The quantity of the substance taken for analysis is 2·5 grammes.

* *Zeitschrift für praktische Geologie*, vol. viii. pp. 370–382.

The Analysis of Blast-Furnace Slag.—H. Joüet * gives a scheme for the analysis of blast-furnace slag. One gramme is fused with potassium and sodium carbonates, and the solution obtained from it is used to determine the silica and sulphur. After the removal of these constituents the solution is divided into two parts. One representing 0·4 gramme is used for determining titanium, then phosphorus, and then the iron. The other part of the solution, representing 0·6 gramme of the sample, is used for the estimation of manganese by precipitation as acetate, and the filtrate therefrom is used to determine the nickel, cobalt, and finally the lime and magnesia. The methods adopted are described, and also those used for finery slag, Bessemer slag, basic slag, and tap cinder.

T. Ulke † determines the lime contents of blast-furnace slags by dissolving 0·5 gramme of slag in boiling nitric acid, neutralising with ammonia, and precipitating the lime at once with ammonium oxalate. The calcium oxalate formed is then treated with permanganate.

Determination of Phosphoric Acid in Basic Slag.—A. N. Papez ‡ states that the conventional methods for the estimation of the citrate solubility, the citric acid solubility, the solubility in 5 per cent. formic acid, and the total phosphoric acid, all give satisfactory results. As regards the Austrian nitric acid method for estimating the phosphoric acid, the author recommends boiling the slag with nitric acid of specific gravity 1·25.

Norbert von Lorenz § states that mineral phosphates almost invariably contain fluorides; therefore, when fluorine is present in a basic slag, an admixture of mineral phosphate is probable. The method formerly recommended by the author is not suitable for basic slag on account of its being interfered with by the presence of sulphides. To detect fluorine in basic slag, the convex side of the watch-glass is covered with a piece of filter-paper moistened with a 5 per cent. aqueous solution of soda; the paper is then washed with a little water, and the liquid is tested for fluorine by adding acetic acid and

* *School of Mines Quarterly*, vol. xxii. pp. 140-152.

† *Moniteur Scientifique*, vol. xiv. ii. p. 775.

‡ *Chemisches Centralblatt*, 1900, ii. pp. 1213-1214; *Journal of the Chemical Society*, vol. lxxx. pp. 192-193.

§ *Chemisches Centralblatt*, 1900, ii. p. 1213; *Journal of the Chemical Society*, vol. lxxx. p. 193.

calcium acetate. A turbidity or precipitate, either before or after boiling, shows the presence of fluorine. Superphosphates, bone-meal, and animal charcoal may be similarly tested for mineral phosphates.

III.—*FUEL ANALYSIS.*

Heating Value of Fuel.—Hermann Langbein * has written a lengthy paper containing a very large number of full analyses of wood, peat, lignite (brown coal), briquettes, coals, anthracite, and coke; also paraffin oil, petroleum, benzines, &c. It is stated that the heating values of these substances is better obtained by direct experiment than by calculation from the elementary composition. The author prefers using a Kröker's bomb, the crucible of which is lined with platinum foil instead of being enamelled. Full particulars are given as to the best methods of operation and calculation.

Determination of Phosphorus in Coke and Coal.—According to J. M. Camp,† the coke, powdered to pass through a forty-mesh sieve, is dried at 100° for an hour, and when cool 5 grammes are exposed in a porcelain crucible in a muffle overnight; the contents are next morning transferred to a platinum crucible, supported on a platinum tripod, on the top of the chimney of an Argand burner, and heated below boiling with 5 cubic centimetres of dilute hydrochloric acid (1:2) and 10 cubic centimetres of dilute hydrofluoric acid until dry, further dried, but not baked, allowed to cool, and warmed with 15 cubic centimetres of the dilute hydrochloric acid. The contents are transferred to an evaporating dish, boiled for one or two minutes with 5 cubic centimetres of strong nitric acid, filtered, treated with 25 cubic centimetres of strong ammonia, and then with sufficient strong nitric acid to exactly dissolve the precipitate, after which 5 cubic centimetres more is added. Precipitation with molybdate follows, and 1·63 per cent. of the dried precipitate is taken as phosphorus.

* *Zeitschrift für angewandte Chemie*, 1900, pp. 1227-1238, 1259-1272; *Journal of the Chemical Society*, vol. lxxx. p. 128.

† *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xvi. pp. 55-56.

STATISTICS.

CONTENTS.

I.—*UNITED KINGDOM.*

Mineral Statistics.—According to the official report of Her Majesty's Inspectors of Mines,* the production of coal in the United Kingdom in 1900 amounted to 225,170,163 tons. The production during the previous year was 220,094,781 tons. There were employed at mines under the Coal Mines Inspection Acts 780,052 persons.

The British production of iron ores under the Coal and the Metalliferous Mines Acts was—

	Tons.
Coal Mines Act	7,667,578
Metalliferous Mines Acts	1,863,714
Total	9,531,292

Sir Lowthian Bell † discusses the question of American competition with the iron and steel trade of Great Britain. Considerations of the cost of carriage lead him to take an optimistic view of the future in his own country.

* "Mines and Quarries; General Report and Statistics for 1900," Part I. pp. 10-11.
† Presidential Address to the Institution of Junior Engineers, December 1900.

A short description * of the Elswick Works has appeared accompanied by excellent illustrations. The establishment at the present time employs 25,000 workmen. Mention is made of the productions of the firm.

Iron Trade Statistics.—The British Iron Trade Association reports † the production of iron and steel in the United Kingdom in 1900 to have included—

	Tons.
Total pig iron	8,908,570
Wrought iron	1,162,765
Bessemer steel ingots	1,745,004
,, ,, acid	1,253,903
,, ,, basic	491,101
,, ,, rails	759,844
Open-hearth steel ingots	3,156,050
,, ,, acid	2,862,566
,, ,, basic	293,485

Imports and Exports.—According to the Board of Trade returns,‡ the exports from the United Kingdom during 1900 were as follows :—

	Tons.
Pig iron	1,428,549
Hoops, sheets, and plates	85,022
Bar, angle, bolt, and rod	157,114
Railroad iron	463,960
Wire	38,488
Tin-plates	273,955
Cast and wrought	339,470
Unwrought steel	308,390
Steel and iron manufactures	42,263

The imports were as follows :—

Iron ore	6,297,873
Pig iron	181,151
Bar, angle, bolt, and rod	80,154
Unwrought steel	179,341
Girders, beams, and pillars	93,176
Unenumerated	225,468
	759,290

Coal Resources.—Further discussion has taken place § as to British coal resources at the close of the nineteenth century. E. Hull deals

* *Engineering Magazine*, vol. xx. pp. 491–503.
† *Iron and Coal Trades Review*, vol. lxii. pp. 669, 770, 1302.
‡ *Ibid.*, vol. lxii. p. 351.
§ Discussion at the Constitutional Club; *Colliery Guardian*, vol. lxxx. p. 969.

with the present increase of consumption and its causes, with questions of export and of deep mining. An export tax is advocated.

The annual report of C. Le Neve Foster to the Home Office deals at considerable length with the output and prices of coal during the year 1899.

II.—*AUSTRALASIA.*

Mining in New South Wales.—A recently issued pamphlet by T. A. Coghlan * deals generally with the mining industry of New South Wales, and contains a map of the country showing the localities of the leading minerals. In 1899 over 10,000 workmen were employed in coal-mining out of 42,820 miners. Iron ore deposits are rich and are widely extended, but are not worked at the present time for the manufacture of pig iron, but some scrap is worked up in the country and some castings are made. The coal deposits, as is well known, are enormous, and are extensively worked wherever the railway or other transport facilities are sufficiently well developed. A sketch of the different fields and their production is given. In 1899, 96,530 tons of coke were also made. Kerosene shale is also worked.

The production † in 1899 included 4,597,028 tons of coal and 36,719 tons of shale.

The usual return compiled by the New South Wales Department of Mines ‡ shows that the output of coal and shale and of coke during 1900 was made up as follows:—Northern district, 3,926,584 tons; southern district, 1,265,055; western district, 315,358; or a total of 5,507,497 tons. All the returns are to hand except from one very small colliery in the northern district, which will not affect the result. The above is a total increase of 810,469 tons over the year 1899, and made up in the several districts as follows:—Northern district, 666,876 tons; southern district, 145,522 tons; western district, 98,041 tons. The total value of the coal at pit's mouth has been returned at £1,668,911, 3s. 7d., as against £1,325,798, 12s. 5d. for 4,597,028 tons in 1899. Oil shale worked during 1900 amounted to 22,862 tons, valued at £20,651, 13s., as compared with 36,719 tons valued at

* "The Mining Industry of New South Wales:" Government Printer, Sydney, 1900.
† "Annual Mining Report of the Department of Mines," Sydney, 1900.
‡ *Mining Journal*, vol. lxxi. p. 281.

£40,823, 5s. in 1899. Coke manufactured during 1900 amounted to 126,213 tons, valued at £109,620, 2s. 6d., as compared with 96,530 tons, valued at £77,129, 10s. 1d. in 1899.

Coal-Mining in Queensland.—According to the Annual Report of the Under-Secretary for Mines for the year 1899, the output of coal was 494,009 tons, and the number of persons engaged in coal-mining was 1142. The Report also notes that 735 tons of manganese ore, valued at £251, was raised.

III.—*AUSTRIA-HUNGARY.*

Mineral Statistics of Austria.—The Austrian official statistics * show that in the year 1899 there was produced in Austria :—

	Production.	Increase or Decrease as Compared with Previous Year.
	Metric Tons.	Per Cent.
Iron ore	1,725,144	−0·49
Manganese ore	5,411	−11·76
Graphite	31,819	−3·76
Asphalt rock	2,635	+309·83
Brown coal	21,751,794	+3·17
Coal	11,455,139	+4·64
Forge pig iron	872,352	+4·13
Foundry pig iron	124,033	+3·30
Total pig iron	996,385	+4·02
Brown coal briquettes	53,027	−7·74
Coal briquettes	71,783	...
Coke	1,226,910	+14·86

The iron and manganese ores used in the blast-furnace amounted to 2,070,392 tons of iron ore and 6616 tons of manganese ore. Of this quantity 560,974 tons was imported ore. In the iron ore mines 5362 workpeople were employed, an increase of 32 as compared with the previous year; and at the ironworks 6197, an increase of 29. Of the 79 blast-furnaces, 54 were in blast for 2350 weeks, the respective numbers for 1898 being 82, 53, and 2416.

* *Statistisches Jahrbuch des k.k. Ackerbau-Ministeriums*, Vienna, 1900.

The production of brown coal in Austria in 1899 was as follows:*—

	Production.	Increase or Decrease as Compared with 1898.
	Metric Tons.	Per Cent.
Bohemia	17,959,855	+3·37
Lower Austria	13,590	+380·86
Upper Austria	363,532	−9·96
Moravia	148,670	+3·49
Silesia	991	+1·95
Styria	2,623,586	+4·57
Carinthia	94,524	−1·20
Tyrol	23,190	+3·71
Carniola	244,801	−1·20
Dalmatia	111,454	−0·57
Istria	98,643	+8·84
Galicia	68,958	−13·00
In all Austria	21,751,794	+3·17

The increase in quantity as compared with the production in 1898 amounted to 668,434 tons. The total value of the production in 1899 was £3,965,310, an increase of 9·41 per cent. on the previous year. It will be observed that 82·57 per cent. of the output was obtained in Bohemia, and 12·06 per cent. in Styria. The exports, chiefly to Germany, comprised 8,669,496 tons of brown coal and 32,460 tons of brown coal briquettes, representing an increase of 705,476 tons of the former and a diminution in the case of the latter of 771 tons. The workmen employed in brown coal mining numbered 50,790, an increase of 1100 as compared with 1898.

In coal-mining 62,943 workpeople were engaged, an increase of 2134. The production of coal was as shown in the following table:—

	Production.	Increase or Decrease as Compared with 1898.
	Metric Tons.	Per Cent.
Bohemia	4,070,383	+0·67
Lower Austria	54,682	+5·42
Moravia	1,613,669	+6·91
Silesia	4,805,709	+5·66
Styria	44	−89·09
Galicia	910,652	+14·67
In all Austria	11,455,139	+4·64

* *Oesterreichische Zeitschrift für Berg- und Huttenwesen*, vol. xlix. pp. 134–136.

The total value was £3,729,180, an increase of 8·77 per cent. The total exports comprised 1,239,809 tons of coal and 475,209 tons of coke. In the Rossitz district 55,719 tons of coal briquettes were made, and 16,064 tons in Moravian Ostrau.

Nickel and cobalt were not produced in Austria in 1899, only speiss and salts being made.* Tungsten ores, as hitherto, were only found in the Zinnwald, Bohemia, and were obtained from old dumps and fillings. Forty-four workpeople were engaged in this. Manganese ores were obtained in small quantities in Bohemia, 2439 tons in the Bukowina, and 2964 tons at Vigunsica in Carniola. These latter were worked up at the iron blast-furnaces at Jauerburg and Servola. The workmen numbered 191, an increase of 50.

Graphite was mined at a number of places in Bohemia, in Lower Austria, Moravia, and Styria, 46·75 per cent. being produced in Bohemia, 27·60 in Moravia, and 22·48 per cent. in Styria. The number of the workpeople employed was 1549, an increase of 159. Asphalt rock was mined at Seefeld and Scharnitz in the Tyrol, and at Vrgorac in Dalmatia. At the first place the rock was worked on the spot for oils and asphalt, while at the latter place part was sold and part retained in connection with a new works about to be erected. The workpeople numbered 129, an increase of 29.

Petroleum and Ozokerite in Galicia.—The official statistics † for the year 1898 show that there were then in operation 242 undertakings for the winning of petroleum, while the workpeople numbered 5902, an increase of 365, and the production amounted to 323,142 tons, an increase of 17·42 per cent. on the year. There were 44 active ozokerite undertakings employing 5413 workpeople, a diminution of 994, and producing 7759 tons, an increase of 12·75 per cent.

Accidents in Austrian Mines.—In the year 1898 there were 162 fatal and 932 severe accidents at Austrian mines, a decrease of 6 in the deaths, but an increase of 112 in the severely injured. This was at the rate of 1·301 per 1000 deaths and 7·487 per 1000 severely injured. In coal-mines there were 55 fatal and 377 severe accidents, in brown coal mines 85 fatal and 442 severe, and in iron ore mines 5 fatal and 41 severe accidents. The causes of these are given.‡

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlix. pp. 119-121.
† *Statistisches Jahrbuch des k.k. Ackerbau-Ministeriums*, Vienna, 1900.
‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. p. 660.

Brown Coal in Bohemia.—The Aussig-Teplitz Railway has issued detailed statistics of the Bohemian brown coal trade for 1899. The output in the Elbogen-Falkenau district, with 5888 workmen, was 2,325,984 tons, and that in the Teplitz-Brüx-Komotau district, with 25,520 workmen, was 15,571,630 tons. The total production was, therefore, 17,897,614 tons.*

The Mining School at Leoben.—Statistics are published † showing the steadily increasing numbers of the students attending the mining school at Leoben, Austria. Details are given for each of the years 1890–1891 to 1899–1900. During this period the annual total of students increased from 142 in the former year to 261 in the latter. This latter year 199 were from Austria-Hungary and 52 from other countries.

Iron Trade Statistics of Hungary.—There was an increase in 1899 of 1·36 per cent. as compared with the statistics for the previous year in the area leased for mining purposes.‡ Of this total area 58·1 per cent. was for coal-mining and 17·9 per cent. for iron ores.

Details are given as to the various appliances in use at the coal, iron ore, and other mines, and as to the concentrating floors. The coke-ovens numbered 172, the same number as in the previous year. The coal-working plants also showed no change in number, being 22 in all. At the iron and other smelting works there were 66 large blast-furnaces, a number of blast-furnaces of smaller size, seven cupolas, and numerous other furnaces of various kinds. The reverberatory furnaces of all sorts numbered 37 in 1899 and the same number in 1898.

In the Zalatna mining district experiments have been made as to the possibility of coking the Urikánya coal. For this purpose thirty coke-ovens were erected. The coke, however, contained 1·5 per cent. of sulphur.

The total number of workpeople employed at Hungarian mines and collieries in 1899 was 60,797 men, 1925 women, and 6389 children, an increase of 1125 men, 276 women, and 36 children as compared with the previous year. Rather over a fourth of the men were employed at mines other than those of coal or iron ore, and 1055 of the men, 49 women, and 166 children were employed at works other

* *Glückauf*, vol. xxxvi. p. 941.
† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlix. p. 161.
‡ *Ibid.*, pp. 56–58.

than ironworks. The wages paid are also mentioned, as well as the chief mines or works, and the number of workpeople they employed.

In 1899 there were 105 fatal accidents and 198 severe ones as compared respectively with 87 and 200 in the previous year. The production was as follows:—

	1899.	1898.
	Metric Tons.	Metric Tons.
Brown coal	4,292,584	4,206,694
Coal	1,238,855	1,239,499
Briquettes	31,138	31,781
Coke	10,336	8,190
Pig iron	451,637	448,621

The iron ore exported from Hungary amounted in 1899 to 593,779 tons, and in 1898 to 499,785 tons. Of asphalt 3060 tons was raised in 1899 and 3125 tons in 1898, the oil won amounting respectively to 2125 tons, and 2471 tons in the two years. The unrefined asphalt rock exported amounted to 2591 tons in 1899 and to 19,074 tons in 1898.

The manganese ore exported was 5073 tons in 1899 and 8028 tons in the preceding years. The total value of the mineral and metallurgical products of Hungary was in 1899 about £4,200,000, or 4 per cent. more than in the preceding year.

IV.—*BELGIUM.*

Iron Trade Statistics.—The iron trade statistics for Belgium for the year 1899 included:*—

	Year 1899.
	Metric Tons.
Coal	22,072,068
Coke	2,304,607
Briquettes	1,276,050
Iron ores	201,445
Manganese ores	12,120
Forge pig iron	317,029
Foundry pig iron	84,165
Acid Bessemer pig iron	169,664
Basic pig iron	453,718
Finished iron wares—	
Sheets	97,604
Others	377,594
Finished steel wares	633,950

Coal was produced in 1899 at 259 places, which gave employment in all to 125,258 workpeople. The average thickness of the seams won

* *Annales des Mines de Belgique*, vol. v.; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlix. pp. 69-70.

was 26·4 inches, and the average working depth was about 1420 feet. Altogether 5990 horses were employed, 4659 being at work underground. The production of coal in 1899 was 16,267 tons less than it was in the preceding year, but the value of the coal produced, on the other hand, increased by as much as £1,262,200, the average value per ton being 1·43 franc (say 1s. 1½.) more in 1899 than it was in 1898. The total wages paid amounted to 146,240,500 francs, and the other outgoings to 90,360,200 francs. The total cost was 10·72 francs per metric ton of coal raised, its average selling value being placed at 12·43 francs. The average workman's wage was 1150 francs. The average wage per shift below surface was 4·37 francs per man, and 2·73 francs above surface per man. The total coal won per man at the working face was 968 tons, 239 tons for each man employed below ground, or 176 tons as an average for the whole of the men employed at the colliery. There were nine strikes in 1899, one of which lasted 33 days, the remainder under a week. Seven of the strikes were for higher wages. The loss of time during the great strike in April and May amounted to 1,146,300 working days. The whole of the other strikes only involved a loss of 6000 days.

The accidents in 1899 were as follows:—

	Total.	Deaths.	Injured.
At collieries	273	121	163
At metal mines	2	1	1
At smelting works	49	26	24
Totals	324	148	188

This was considerably below the average. Of the 121 deaths at collieries, 23 were in shafts and 48 by falls of rock, only 6 resulting from explosions. The fatal accidents above ground numbered 20.

The following tabular statements are of interest, as showing the progress made by the Belgian iron trade during the past five years. The coal statistics were as follows:*—

Year.	Active Collieries.	Production.	Value per Ton.
		Metric Tons.	Francs.
1895	261	20,457,604	9·45
1896	262	21,252,370	9·51
1897	256	21,492,446	10·26
1898	257	22,088,335	11·00
1899	259	22,072,068	12·43

* *Stahl und Eisen*, vol. xx. pp. 1257-1259.

The steady rise in value is most noticeable. The workpeople employed and their wages were as follows :—

Year.	Workpeople Employed.	Annual Average Wage per Workman.
		Francs.
1895	118,957	948
1896	119,246	980
1897	120,382	1,023
1898	122,846	1,097
1899	125,258	1,168

For the year 1899 the production of coal in each of the provinces of Belgium was as follows :—

	Metric Tons.
Hennegan	15,581,380
Namur	641,360
Liége	5,849,328
Total	22,072,068

The collieries were served by 2381 steam-engines of 153,927 horse-power.

The proportion of coke has been as shown in the following table :—

Year.	Number of Works.	Ovens in Use.	Ovens not in Use.	Coal Coked.	Coke Made.
				Metric Tons.	Metric Tons.
1895 . .	...	3,233	2216	2,358,663	1,749,109
1896 . .	...	3,555	1208	2,709,720	2,004,430
1897 . .	45	3,845	995	2,968,620	2,207,840
1898 . .	42	4,028	813	2,944,096	2,161,162
1899 . .	44	4,276	657	3,121,155	2,304,607

The number of workpeople employed, and the average value of the coke produced, has been :—

Year.	Workpeople Employed.	Average Value per Ton of Coke.
		Francs.
1895	2,130	13·75
1896	2,415	14·22
1897	2,566	17·13
1898	2,519	18·75
1899	2,894	20·50

Similar details are given as to the manufacture of briquettes. This industry does not seem to make much progress. In 1895, 1,217,795 tons of briquettes were made at 38 works, and in 1899 at 37 works, with 64 presses in operation and 23 not in use, 1234 workpeople made from 1,152,880 tons of coal, 1,276,050 tons of briquettes of an average value of 16·05 francs per ton.

The imports of coal, coke, and briquettes have been :—

Year.	Coal.	Coke.	Briquettes.
	Metric Tons.	Metric Tons.	Metric Tons.
1895	1,530,364	362,834	3,452
1896	1,693,376	260,273	1,561
1897	2,017,344	269,606	632
1898	2,202,517	280,590	1,756
1899	2,844,274	296,508	10,725

The exports have been as follows :—

Year.	Coal.	Coke.	Briquettes.
	Metric Tons.	Metric Tons.	Metric Tons.
1895	4,661,477	870,983	459,702
1896	4,649,799	863,067	459,974
1897	4,448,544	909,486	615,074
1898	4,579,955	878,435	666,265
1899	4,568,938	1,008,740	525,625

The production of iron and manganese ores shows a steady diminution, as the following table shows :—

Year.	Production of Iron Ores.	Production of Manganese.
	Metric Tons.	Metric Tons.
1895	312,637	22,478
1896	307,031	23,265
1897	240,774	28,372
1898	217,370	16,440
1899	201,445	12,120

During 1899 there were in Belgium at 16 works, 36 blast-furnaces in blast, and 4 not in use. The men employed numbered 3788, and they earned an average of 3·33 francs per day. There were smelted 229,186 tons of Belgian ore, 2,714,381 tons of foreign ore, and 260,573 tons of slag and scrap iron, there being also used in the

furnaces 364,380 tons of limestone, 1,126,808 tons of Belgian coke, 141,938 tons of imported coke, and 16,473 tons of coal. The production of pig iron amounted to 1,024,576 tons, valued at 72·61 francs per ton. The details were as follows :—

Year.	Forge.	Foundry.	Ferro-Manganese.	Bessemer.	Basic.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
1895 . .	329,750	85,950	...	161,600	252,428
1896 . .	362,451	84,275	11,391	193,518	307,779
1897 . .	426,332	78,410	12,636	183,701	333,958
1898 . .	308,875	93,645	6,259	173,085	397,891
1899 . .	317,029	84,165	...	169,664	453,718

The total production and the average value per ton was as follows :—

Year.	Total Production of Pig Iron.	Value per Ton.
	Metric Tons.	Francs.
1895	829,234	48·24
1896	959,414	53·76
1897	1,035,037	58·66
1898	979,755	59·10
1899	1,024,576	72·61

The average value in 1899 was thus over 50 per cent. more than it was in 1895. While the production in 1899 was less than it was in 1897, it has increased by over 23 per cent. as compared with the production in 1895. The production of basic pig iron increased by as much as 80 per cent. during this period.

The production of wrought iron and steel has been as follows :—

Year.	Wrought Iron.	Value per Ton.	Steel.	Value per Ton.
	Metric Tons.	Francs.	Metric Tons.	Francs.
1895	445,899	124·98	367,947	115·27
1896	494,032	129·95	519,311	121·56
1897	474,819	135·61	527,617	132·34
1898	485,040	135·93	567,728	134·94
1899	475,198	160·85	633,950	151·67

Wrought iron, it will be seen, has little more than held its ground since 1895, and has diminished as compared with 1896. Steel, on the

other hand, has increased by as much as 72·5 per cent. There were 46 active wrought iron works in Belgium in 1899, with 340 active puddling furnaces, and 55 not in use. They consumed 350,020 tons of Belgian pig iron and 135,470 tons of imported pig iron. Further details are given as to these works and their products.

The works making steel numbered 15 in operation and 2 closed down. The active open-hearths and similar furnaces numbered 11, with 4 not at work. Of converters, 25 were in operation and 15 not blowing. The workpeople numbered 7681, earning an average daily wage of 3·78 francs. Details are given as to the consumption of raw materials, and as to the various products. The pig iron consumed was 620,812 tons of Belgian metal and 125,184 tons of imported iron. The scrap consumed was 125,184 tons, and the ingots made 731,249 tons. The finished products amounted in quantity to 633,950 tons, as shown in the table. Of this, various kinds of rolled metal amounted to 340,355 tons, and rails to 123,119 tons.

In 1900 Belgium* produced 1,018,507 tons of pig iron, 362,252 tons of wrought iron, and 654,827 tons of steel ingots.

V.—*CANADA.*

The Iron Industry.—F. Krall † discusses the iron industry of Canada. This, he points out, is developing very rapidly, thanks to the fostering efforts of the Government, which grants at present as much as 12s. 6d. for each ton of pig iron made from Canadian ores. For certain steel products as much as 29s. 2d. is paid in this way, while in Ontario the royalties on certain ores are not enforced if they are smelted in the Dominion. The author enumerates the more important iron and steel works in the Dominion. A number of large iron and steel works, rolling-mill, and other smelting works are in course of erection. In many cases important financial assistance has been promised towards their erection by the local authorities where the works are to be erected. A large steelworks, for instance, is being erected at Hamilton, Ontario. Another has been laid down by the Nickel Steel Company of Canada, which is arranged for a daily out-turn of from 1200 to 1500 tons of nickel steel rails and 400 tons of nickel steel plates. A charcoal blast-furnace is being erected at Fort William;

* *Comité des Forges de France*, Bulletin No. 1741.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlix. p. 83.

at Collingwood iron and steel works are to be erected, with a daily out-turn of 200 to 250 tons of pig iron and 95 tons of steel; at Welland the Canadian Steel Company is arranging large blast-furnaces and steel-works, whose daily out-turn of rails, girders, plates, &c., is to be 1000 tons; others are also mentioned.

It appears * that the Canadian production of iron last year was about 100,000 tons, and that the consumption was about eight times that amount, but rapid strides are being made in the output. There are now four large smelting works—three in Ontario and one in Sydney, Cape Breton.

J. S. Barrie † describes the development of iron and steel in Eastern Canada, with reference to the supply of coal and ore, and the present condition of the works in the country.

A. J. Moxham ‡ gives somes notes on the future of the steel industry in Canada. Ore and coal supplies, transport, costs, and other matters are discussed in a favourable light.

E. Gilpin § gives a number of analyses of ore, flux, fuel, and pig iron shown by the Nova Scotia Steel Company and others at the Paris Exhibition.

Mining Industry of Ontario.—In Ontario eight iron mines were worked in 1899, yielding 16,911 tons of ore. ||

Coal and Iron Ore in British Columbia.—The official statistics for the year 1899 show that in that year there was raised in British Columbia 1,306,324 tons of coal and about 2000 tons of iron ore. The coke made was 34,251 tons. This is an increase of 170,459 tons of coal and 750 tons of coke as compared with the output of the previous year.

The Mining Industry of Newfoundland.—According to a return furnished by J. P. Howley, Director of the Geological Survey of Newfoundland, the production of iron ore in that colony during 1899 amounted to 306,880 tons against 102,000 tons in the previous year. The production of coal was 5000 tons. Newfoundland is not embraced in the Dominion of Canada.

* *Engineering*, vol. lxxi. p. 84.

† *Journal of the West of Scotland Iron and Steel Institute*, vol. viii. pp. 67–80.

‡ Paper read before the Canadian Manufacturers' Association; *American Manufacturer*, vol. lxviii. pp. 321–324.

§ *Transactions of the Nova Scotia Institute of Science*, vol. x. pp. 262–267.

|| Report of the Bureau of Mines, Toronto, 1900.

VI.—*CHILI.*

Manganese Ore. — The exports of manganese ore from Chili in 1899 amounted to 23,000 tons. In the ten years from 1889 to 1898 the total exports amounted to 344,087 tons. The greatest amount exported was 51,686 tons in 1892.

VII.—*CHINA.*

Mining Industry.—Doumer * advocates the starting of ironworks in Indo-China. Coal is met with in abundance, and the iron ore deposits at Thai-Nguyen, in Tonkin, are well situated for economical working. Ore could be supplied at the works at 4 francs a ton, and coal at 7 francs a ton.

Leclère † gives an account of the mining law of China.

VIII.—*CUBA.*

Iron Ore.—In 1900 the exports of iron ore from Cuba amounted to 445,679 tons, all of which went to the United States.

IX.—*FRANCE.*

Iron Trade Statistics.—In 1900 the production of pig iron ‡ in France amounted to 2,699,494 tons, that of wrought iron to 745,312 tons, and that of steel ingots to 1,624,048 tons. Of the steel ingots 954,261 tons were made by the Bessemer process, and 669,787 tons by the open-hearth process.

Details are given § as to the blast-furnaces existing in France at the commencement of 1901. These included—

	Total Number.	Total in Blast.	Capacity of those in Blast.
			Tons.
Eastern District . .	81	65	5,373
Northern District .	20	14	1,375
Central, South, and West France .	53	36	2,022

The furnaces at the various works are shown in detail.

* *Echo des Mines et de la Métallurgie*, vol. xxviii. pp. 240-245.
† *Annales des Mines*, vol. xviii. pp. 249-260.
‡ *Comité des Forges de France*, Bulletin No. 1756.
§ *Echo des Mines et de la Métallurgie*, vol. xxviii. pp. 2-3.

Coal.—An exhaustive statistical article has been published by Noel * on the French coal trade. Statistics of production are given from 1820 to the present time. In 1820 the French collieries furnished 79 per cent. of the consumption, which was 1,348,060 tons. In 1899 they furnished 74 per cent. of the consumption, which was 45,600,000 tons.

A book has been published by L. Bailly on the economic and financial future of the French coal and iron trades.

Imports and Exports.—The French imports and exports † in 1900 included :—

	Imports.	Exports.
	Tons.	Tons.
Coke	1,572,520	69,200
Iron ore	2,119,003	371,799
Pig iron	149,857	114,371
Wrought iron	58,590	33,718
Steel	21,191	21,046

The Paris Exhibition.—H. Schmerber ‡ gives a detailed description of the mining exhibits at the Paris Exhibition. With the aid of numerous illustrations, he describes the exhibits of the Bruay collieries, the Vicoigne and Noeux collieries, the Béthune collieries, the Dourges collieries, the Courrières collieries, the Blanzy collieries, and several smaller mines. The mining exhibits have also been described by A. Habets § and by H. Lallement.||

G. Bresson ¶ describes the metallurgical exhibits at the Paris Exhibition.

H. Wedding ** publishes a report of a tour, under his personal guidance, of the students of the Berlin School of Mines to the Paris Exhibition. He briefly explains the different branches of the metallurgy of iron, and describes in this connection the various objects displayed, with special reference to new constructions and processes. He deals

* *Revue Scientifique*, April 6, 1901.
† *Comité des Forges de France*, Bulletin No. 1720.
‡ *Génie Civil*, vol. xxxviii. pp. 216–221.
§ *Revue Universelle des Mines*, vol. li. p. 101.
|| *Berg- und Hüttenmännische Zeitung*, 1900, pp. 488, 501.
¶ *Revue Universelle des Mines*, vol. li. pp. 242–266.
** *Verhandlungen des Vereins zur Beförderung des Gewerbfleisses*, 1900, pp. 307–341; illustrated.

with the subject under the several heads of :—Iron ores and their occurrence; the improvement of existing ores; the ores of metals other than iron; the production of pig iron; blast-furnaces; blast-furnace gases as a source of power for driving motors; malleable iron; additions to molten iron; finished iron; rock-drilling machines; and various kinds of mine-pumps.

The metallurgical exhibits at Paris have also been described by G. Odelstierna * and by O. Westerberg.†

H. Guérin ‡ discusses the influence of the last Paris Exhibition on the steel industry in France, and traces the development due to the exhibitions held in 1855, 1867, 1878, and 1889. The increased use of the basic process and of the open-hearth furnace, and the substitution of steel for iron castings, are the subjects which receive especial attention.

X.—*GERMANY.*

Mineral Statistics.—The definite figures of mineral production in the German Empire and Luxemburg in 1899 have been issued. They include the following :—

	Metric Tons.
Coal	101,639,753
Lignite	34,204,666

The official mineral statistics of the German Empire and Luxemburg for 1900 are published.§ The following are the leading items :—

	Metric Tons.
Coal	109,271,726
Brown coal	40,279,332
Graphite	9,248
Asphalt	89,685
Petroleum, gallons	50,375
Iron ore	18,964,367
Manganese ore	59,203

Iron Trade Statistics.—H. Rentzsch,‖ in quoting from the German official statistics, shows that the iron trade production in Germany, including Luxemburg, in 1899 was as follows :—

* *Bihang till Jernkontorets Annaler*, 1901, pp. 69–83.
† *Ibid.*, pp. 83–93.
‡ *Engineering Magazine*, vol. xx. pp. 1043–1054.
§ *Glückauf*, vol. xxxvii. p. 335.
‖ *Stahl und Eisen*, vol. xx. pp. 1285–1289.

Producing iron ore mines	565
Iron ore raised, metric tons	17,989,635
Workpeople employed	40,917
Active blast-furnace works	108
Charcoal pig iron made, tons	10,321
Coke and mixed pig iron	8,132,811
Value per ton, shillings	55·98
Ores and slags charged, tons	20,545,309
Workpeople employed	36,334
Total blast-furnaces	285
Blast-furnaces in blast	263
Weeks in blast	12,806
Foundry pig iron, tons	1,383,897
Bessemer and basic pig iron	5,475,399
Forge pig iron	1,222,687
Direct castings	48,672
Scrap	12,477

The foundries numbered 1213 in 1898 and 1238 in 1899, and they gave employment to 85,435 workpeople in the former year and 91,613 in the latter. They worked up 1,824,165 tons of pig iron and scrap in 1898 and 91,613 tons in 1899, producing 1,597,434 tons of castings in 1898 and 1,776,878 tons in 1899.

The works making wrought iron and steel and their products were as follows:—

Producing works	175
Workpeople	37,667
Semi-manufactures, tons	79,232
Value per ton, shillings	107·58
Manufactures, tons	1,124,627
Value per ton, shillings	158·04

Similar details relating to the works making ingot metal show:—

Producing works	177
Workpeople	120,983
Semi-manufactures, tons	1,508,391
Value per ton, shillings	91·94
Manufactures, tons	4,820,275
Value per ton, shillings	145·31

The rail and rail-fastenings made in 1898 amounted to 807,171 tons, and in 1899 to 792,013 tons.

The total quantity of castings, iron and steel, produced for sale has risen from 7,764,276 tons in 1897 to 9,358,075 tons in 1899.

The production of coal and brown coal has been as follows :—

Coal, tons	101,639,753
Value per ton, shillings	7·77
Brown coal, tons	34,204,666
Value per ton, shillings	2·29

The workpeople employed at the collieries numbered 357,695 in 1898 and 378,575 in 1899, and at the brown coal mines 42,812 in 1898 and 44,745 in 1899.

The estimated* production of pig iron in Germany, including Luxemburg, was as follows for the year 1900, the official figures for the year 1899 being also shown :—

Pig Iron.	1900.	1899.
	Metric Tons.	Metric Tons.
Forge and spiegeleisen	1,612,664	1,222,687
Bessemer	495,790	5,475,399
Basic	4,826,459	
Foundry	1,487,929	1,432,569
Scrap		12,477
Totals	8,422,842	8,143,132

In 1890, the total production of pig iron in Germany was only 4,658,451 tons, so that it has increased by about 80 per cent. in the past decade. The above figures for 1900 do not include charcoal pig iron or scrap. A comparison of the statistics for each of the past ten years is instructive, showing as it does the great alterations that have taken place in the iron industry during that period, and the rapid rise of the basic process of steel-making. Details are given as to each of the chief iron-producing districts.

The share taken by the various districts in the production of pig iron was as follows :—

	Per Cent.
Rhineland-Westphalia	38·8
Siegerland, Lahn, Hessen-Nassau	8·8
Silesia and Pomerania	10·1
Kingdom of Saxony	0·3
Hanover and Brunswick	4·1
Bavaria, Würtemberg, Thuringia	1·7
Saar, Lorraine, Luxemburg	36·2

* *Stahl und Eisen*, vol. xxi. p. 189.

Imports and Exports.—Full details are published * of the iron trade imports and exports of the German Empire for the year 1900:—

Imports.

	1900. Metric Tons.
Iron ore	4,107,790
Slags and slag wool	974,947
Basic Bessemer slag	103,481
Pig iron, scrap, and semi-manufactures	829,873
Rails, sheets, and other manufactures	75,695
Other iron wares	77,527
Machinery	98,684
Total iron and iron wares	983,112

Exports.

	1900. Metric Tons.
Iron ore	3,247,888
Slags and slag wool	32,494
Basic Bessemer slag	174,563
Pig iron, scrap, and semi-manufactures	224,132
Rails, sheets, and other manufactures	928,058
Other iron wares	396,151
Machinery	233,996
Total iron and iron wares	1,548,558

The term "iron" includes steel.

The quantity of coal imported in 1900 was 7,384,049 tons, and of that exported, 15,275,805 tons.† The figures for brown coal were respectively 7,960,313 tons, and 52,795 tons. The manganese ore imported amounted to 204,420 tons, and that exported to 2454 tons, the similar figures for chrome ores being 18,728 and 427 tons. Of coke 512,690 tons were imported and 2,229,188 tons exported; the imports of oils of all kinds, other than coal tar oils, was 1,117,325 tons. There was also imported 1712 tons of metallic nickel, and 29,383 tons of bauxite, the respective exports amounting to 268 and 44 tons. Other details are also given generally for other minerals and metallurgical products.

The Iron Trade of Upper Silesia.—F. Jüngst ‡ shows by means of statistics that the prosperity of the iron industry of Upper Silesia is now no longer based upon the supply of native ores, but upon that of foreign ores. This is notably the case as regards the Swedish ores from Gellivare, and less so as regards the Hungarian and Styrian spathic ores

* *Stahl und Eisen*, March 1, 1901.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlix. pp. 149-150.

‡ *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xlviii. pp. 519-536.

and the Spanish Rio Tinto ores and pyrites residues. The author first passes in review the various reasons which led to the importation of foreign ores, and refers at length to the character, quantity, and value of the imports. He then traces the influence which the use of foreign ores has exercised upon the iron production of Upper Silesia, and the important part played by them in the improvement of blast-furnace practice generally. Recent results are contrasted with those of former years, and analyses are given which show the manner in which the different constituents of the ores affect the chemical composition of the pig iron. The use of foreign ore also favourably affects the working expenses, as may be seen from the following comparative table, which shows the cost of production of one ton of iron at the Gleiwitz ironworks in the years 1871 and 1898 respectively:—

	1871.	1898.
Capacity of blast-furnace, cubic feet	4,340	9,900
Proportion of Upper Silesian brown ore in the charge, cwts.	78·43	20·83
Proportion of iron in the charge, cwts.	32·53	51·61
Production of pig iron in twenty-four hours, tons	20·25	68·76
Coke consumption per ton of iron, tons	2·040	1·079
Contract wages per ton of iron, shillings	3·00	1·53
Blast-furnace labourer's wages per shift	2·23	3·29
Selling price of coking coal, shillings	6·60	6·09
Selling price of coke, shillings	19·00	12·88
Cost of coke per ton of iron produced, shillings	39·86	13·89
Cost of additions per ton of iron produced, shillings	4·60	1·90
Cost of ore per ton of iron produced, shillings	21·85	31·44
Total cost of smelting material and fuel per ton of iron produced, shillings	66·31	47·23
Sundry other working expenses per ton of iron produced, shillings	10·70	7·18
Cost of production of one ton of iron, shillings	77·01	54·41*
Selling price of one ton of pig iron, shillings	86·00	69·00

In conclusion, the opinion is expressed that as the demand for foreign ore increases the ironmakers of Upper Silesia will continue to look to the Swedish deposits as the readiest available source whence to draw the bulk of their supplies, provided that every means are taken to ensure cheap and easy transport.

Iron Ore in Prussia.—In the official mining statistics of the mineral production of Prussia in 1899 the output of all the principal mines is stated, and details are given of improvements in machinery

* 54·31 in original.

and methods introduced.* A statement is given showing the quantity of the various kinds of iron ore raised. The figures are as follows:—

	Tons.
Brown hæmatite	1,007,425
Clay iron ore	25,982
Clay iron ore and limonite	550
Clay iron ore and spherosiderite	9,553
Spathic iron ore	1,801,340
Blackband iron ore	40,182
Red hæmatite	682,944
Magnetite	27,778
Oolitic red hæmatite	85,886
Pisolitic ore	608,725
Bog iron ore	5,210
Total	4,295,575

Mineral Statistics of Saxony.—There were in 1899 in Saxony thirty-one active collieries and ninety active brown coal mines.† The workpeople engaged in coal-mining numbered 23,153, an increase of 309. Of these, 369 were females. The operatives employed in brown coal mining numbered 2584, an increase of 131. Of these, 146 were females. In mining of all kinds, 1304 officials and 28,632 workpeople were engaged, 515 of these being females. There were 518 youths and eight girls employed, these being all under sixteen. The production of coal in 1899 was 4,546,756 tons, an increase of 110,301 tons, and of brown coal 1,292,348 tons, an increase of 111,420 tons. The coal production had an increased value of £121,246, and that of brown coal an increased value of £13,111, as compared with the respective values of these minerals in 1898. In the collieries there were in 1899 twenty-seven fatal accidents, a decrease of one, and in the brown coal mines ten, also a decrease of one. Of iron ore 8038 tons were raised. Pig iron, as heretofore, was made in only one blast-furnace, that of the Königin Marienhütte at Cainsdorf. Here there was made 9550 tons of foundry pig iron and 15,975 tons of forge pig iron, together with 14·3 tons of direct castings. Altogether there were made 25,539 tons of pig iron, valued at £84,505. The blast-furnace was in blast during the whole year, and gave employment to 172 workpeople, twelve of whom were females. The amount of ore smelted was 61,573 tons, and 12,923 tons of other additions were also charged.

* *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xlviii. p. 155.

† *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen auf das Jahr* 1900, pp. 93–140, &c.

Coal.—The statistics of coal production in the German Empire are published.* The output has increased from 73,715,653 tons in 1891 to 109,224,976 tons in 1900. In round figures, the production of the various coalfields in 1900 was as follows:—

	Tons.
1. Upper Silesia	24,782,600
2. Lower Silesia	4,767,400
3. Kingdom of Saxony	4,784,200
4. North Germany	1,156,500
5. Bavaria	706,700
6. Rhineland-Westphalia	60,119,400
7. Inde and Worm basin	1,771,500
8. The Saar	11,136,700

In the German Empire there were 338 collieries in operation, and 413,665 workmen were employed, the output per workman being 264 tons.

The annual production † of the Lower Rhine-Westphalian coal district is now about 59·5 million tons, one-half that of all Germany, and one-fourteenth part of the production of the whole world. According to Schultz, down to a depth of 700 metres there are available some 11 thousand million tons of coal; from 700 to 1000 metres, 18·3 thousand millions; and from 1000 to 1500 metres, 25 thousand million tons, or enough to last for 543 years if an annual output of 100 million tons was maintained. Below this depth there still remains, he estimates, some 75 thousand million tons. These coal deposits correspond with the vast iron ore deposits of Lorraine. The minette district of the Upper Moselle is estimated to contain 3000 million tons of ore.

The annual report of the Westphalian coke syndicate for 1900 is published.‡ The condition of the coke market during the year was satisfactory. In the Dortmund district the production was as follows:—

	Tons.
Output of syndicate coke works	7,786,347
Output of five non-syndicate works	392,300
Output at collieries belonging to ironworks	1,465,510
Total	9,644,157

This represents an increase of 17·5 per cent. over the output in 1899. The number of coke ovens belonging to the syndicate amounted to 8629, of which 2633 were arranged for the recovery of by-products.

* *Glückauf*, vol. xxxvii. pp. 238–241.
† *Stahl und Eisen*, vol. xxi. pp. 190–193.
‡ *Glückauf*, vol. xxxvii. pp. 373–377.

Brown Coal.—The seventh annual report of the Association of Rhenish brown coal producers, covering the year from July 1, 1899, to June 30, 1900, has been published.* The production in 1899 amounted to 3,984,500 tons, or 1,230,000 tons more than in 1898. The output of 2,413,000 tons during the first half of this year shows an increase of 35·3 per cent. over the corresponding period of last year, and warrants the assumption that the year's production will exceed 5,000,000 tons. Great difficulty is experienced in obtaining the requisite supply of labour, notably of mine foremen and subordinate officials.

Dealing with the progress that has been made of late in the Rhenish brown coal industry, especial attention is devoted to the question of brown coal briquettes.† The production of these has increased with great rapidity, yet the demand still exceeds the supply. The production has been as follows in the years mentioned:—

	Metric Tons.
1890	139,990
1893	255,390
1897	530,470
1898	623,130
1899	929,300

The increase has been a steady one year by year, but it will be seen that in 1899 it was as much as 51 per cent. when compared with the output for the year 1898. The exports to Holland and Switzerland amounted to 146,090 tons.

Goods Traffic on German Railways.—The total goods traffic carried on German railways in 1899 amounted to 248,218,010 tons, or an increase of 22·8 per cent. in four years. The iron trade traffic included in 1899:—

	Metric Tons.
Coal	87,488,534
Brown coal	19,211,442
Iron ores	11,003,919
Pig iron	8,171,146
Iron and steel	4,922,509
Rails	1,365,734
Iron and steel wares	1,353,529
Iron boilers	1,342,002
Iron tubes	663,359
Iron and steel wire	550,651
Iron railway sleepers	273,390
Iron axles	255,374

* *Glückauf*, vol. xxxvi. p. 971.
† *Stahl und Eisen*, vol. xx. p. 1299.

The total mineral and metallurgical traffic amounted to 138,922,809 tons, or 56 per cent. of the total quantity.*

Royal Testing Institution.—Details are given as to the number of tests of various kinds made at the Royal testing establishments, Prussia, in the year 1899. Altogether 89 persons were employed at these. The section for the testing of metals had 353 cases submitted, as compared with 295 in the previous year. Some 6730 tests of all kinds were made in connection with these as compared with 4112 in the previous year.†

The Krupp Steelworks.—E. Schroedter ‡ publishes some biographical notes on the founders of the world-famed Krupp Works.

The Iron Industry of Luxemburg.—The official statistics § for the year 1899 show that there were then at work in Luxemburg seventy-two iron ore mines, and these produced during the year 6,014,394 tons of ore. Pig iron was produced at eight ironworks in twenty-eight blast-furnaces. The total quantity made was 982,930 metric tons, including—

	Metric Tons.
Foundry pig iron	137,362
Pig iron for ingot iron	692,966
Forge pig iron	152,602

There were eight foundries at work. These used 11,793 tons of pig iron, and produced 11,154 tons of castings. There was also one steelworks in operation. The total number of workpeople employed at the iron ore mines numbered 6057. Of these, 3714 were employed underground. The blast-furnaces gave employment to 3737 workpeople, the foundries to 310, and the steelworks to 1005, a total of 11,109.

XI.—*GREECE.*

Iron Ore.—In Greece the iron ore mining industry is of greatest importance in the Isle of Seriphos. In 1899 the exports of iron ore amounted to 176,249 tons, of which 80,281 tons went to England, 59,006 to Germany, 15,664 to Austria, 15,135 tons to the United States, and 6263 tons to France.

* *Verkehrs-Correspondenz; Stahl und Eisen*, vol. xx. pp. 1171-1172.
† *Stahl und Eisen*, vol. xxi. pp. 141-143.
‡ *Engineering Magazine*, vol. xx. pp. 519-530.
§ *Comité des Forges de France*. Bulletin No. 1748.
Echo des Mines, vol. xxvii. p. 1291.

XII.—*HOLLAND.*

Coal-Mining.—Holland possesses immense peat bogs and also collieries at Heerlen and Kerkrade. The output of coal in 1899 was 212,973 tons.

XIII.—*INDIA.*

Mineral Statistics.—The mineral production * of India in 1899 included—

	Tons.
Coal	4,937,160
Iron ore	60,725
Manganese ore	87,126
Graphite	1,524

XIV.—*ITALY.*

The Iron Industry.—The recent progress of the iron industry of Italy is stated † to date from the establishment of the Terni Steelworks. Up to that time there were only a few works in Liguria and Tuscany, and some blast-furnaces in Lombardy. The various ironworks of Italy have entered into mutual arrangements for the sale of their produce. As far as finished manufactures are concerned, foreign goods have now been almost entirely excluded from Italy, the Italian works supplying the country, and the iron trade imports being now practically confined to coal, pig iron, and a portion of the semi-manufactures. Italy, as is known, possesses no large coal deposits. A small district in the province of Cuneo produces some anthracite, but all coal for coking purposes has to be imported. The production of pig iron is, therefore, only possible practically where foreign coal can be obtained at cheap rates and ore is available. It is confined to the coast-line opposite the island of Elba. But even here no large blast-furnace plants are lastingly possible, for it is believed that in the course of twenty or thirty years the ore deposits will be exhausted if the annual output of ore continues at from 200,000 to 250,000 tons. In 1898 the company working the Elba mine erected an ironworks at Piombino. Charcoal from Tuscany and from Sardinia is used as fuel. Italy now produces annually only between 20,000 and

* "Statistics of Mineral Production," Calcutta, 1900.

† *Oesterreichische Zeitschrift fur Berg- und Hüttenwesen*, vol. xlix. p. 22.

25,000 tons of pig iron, and is therefore compelled to import about 170,000 tons of pig iron, 150,000 tons of scrap, and from 15,000 to 20,000 tons of semi-manufactures. The Terni works alone use annually about 90,000 tons of imported material, converting this chiefly into railway material and supplies for the fleet. It is anticipated that new blast-furnaces will be erected in Italy. The rolling-mills have recently undergone improvement, and with the enlargement of those at Sestri, it is probable that Italy will soon be in a position to do completely without the present importation of merchant sheets from the United Kingdom, Belgium, and Germany. Finished sheets in small sizes are made at the rolling-mills at Dongo, on the Lake of Como. The import of beams has been largely diminished by the action of the syndicate already referred to, which compels its customers only to import such shapes as are not produced in Italy. As the Savona works now rolls beams up to about 10 inches high, only larger sizes are imported. Formerly large quantities of tin-plate were imported into Italy, but now the Magona works at Piombino supplies nearly the whole quantity required. In 1898 only 1670 tons were imported, 7200 tons being made in Italy. As, however, 1150 tons were exported to the Argentine Republic, only 500 really required to be imported. While the imports of finished material thus diminished very greatly, the quantities of raw materials imported are rapidly increasing.

XV.—*JAPAN.*

The Iron Trade Progress.—C. Löwl * deals with the official statistics issued by the Japanese Ministry for Agriculture, and contrasts as follows the condition of the iron trade in the years 1892 and 1897:—

	1892 Production.	1897. Production.
	Metric Tons.	Metric Tons.
Coal	3,200,435	5,221,437
Petroleum	13,250	42,040
Graphite	509	391
Pig iron	18,864	63,[illegible]
Manganese ore	5,911	15,400

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlix. pp. 136-137.

There were in 1897 113 coal-mines, 1 iron ore mine, and 10 petroleum workings. Other metals are also dealt with. The Kamaïschi ironworks, which has been in operation since 1823, made 16,096 tons of pig iron. The oldest colliery appears to be that of Miike, which is stated to have been in operation since the year 1469. In 1897 it produced 498,000 tons of coal. Other large collieries are those of Yûbari, established in 1876, which produced in 1897 283,964 tons of coal, and the Akaïke, which dates back to 1657, and produced in 1897 166,000 tons of coal. A number of the gold, copper, and other mines date back to the sixteenth and seventeenth centuries. There were in operation in 1897 204 mines of all kinds, and these were provided with 1840 mine engines, most of which were driven by steam. There were 39 dynamos in use.

Mining Statistics.—During the year 1898 there was produced in Japan—

	Tons.
Brown coal	6,598,033
Anthracite	53,175
Coke	44,825
Graphite	347
Pig iron	20,588
Steel and malleable iron	3,021

The quantity of unrefined petroleum raised was 50,533,740 litres.*

In the island of Formosa there are, according to N. Yamasaki, important deposits of gold ore, coal, and sulphur. Petroleum is also met with in small quantities. The coal, which is reserved for the use of the Japanese navy, is of Tertiary age. Some 15,000 tons are raised annually. The best coal is mined at Skikyakutei, Denryoko, and Sanshorei.†

XVI.—*NORWAY.*

Norway as an Iron-Producing Country.—O. Vogel ‡ observes that while Sweden has for centuries been an iron-producing country, Norway is still dependent for its iron on foreign countries. This was not always the case, however. Once upon a time Norway possessed an iron industry that stood worthily by the side of that of Sweden. The

* *Stahl und Eisen*, vol. xx. p. 821.
† *Petermann's Mittheilungen*, vol. xlvi. pp. 221–234.
‡ *Stahl und Eisen*, vol. xx. pp. 1138–1146 and 1199–1204.

author now considers the rise and progress of the iron trade of Norway, and then shows how, despite its great riches in iron ore, the industry gradually died out during the second half of the last century. He also refers to the possibilities the country possesses of again becoming an iron producer.

At what date iron smelting began in Norway is not known with any certainty. Probably the bog and lake ores were the first to be worked. Although in its mountain ranges Norway possesses ores of all kinds, mining in these districts only developed at a comparatively late date, probably in consequence of the local political conditions. The author sketches the early modern history of mining in Norway in some detail, showing the difficulties with which it had to contend. At the present time Norway has only one ironworks, and even this of late has done nothing more than work up iron, not making any. At the middle of the last century Norway possessed seventeen ironworks, of which most were then in full work. The oldest of these was probably the works at Fossum. It was situated a short distance from the town of Skien. Agricola, who died in 1555, refers to it. The Fritzöe works, near the town of Laurvig, was in existence in the middle of the sixteenth century. The third oldest works was an ironworks at Maridalen, which was started in the year 1578. Other works are also mentioned. The only works now in existence is that at Naes, near Tvedestrand. This makes exclusively open-hearth material. At the commencement of the nineties a blast-furnace was at work here which produced weekly from 75 to 100 tons of charcoal pig iron. These ores came from the Klodeberg mine near Arendal, but the absence of railway communication threw great difficulties in the way. In 1897 this works employed 130 workpeople. The principal works at the middle of the last century was that of Count Laurvig. It possessed three charcoal blast-furnaces and eleven charcoal hearths, obtained from the forests belonging to the Count. Not only did the Count possess the right in a large district that no peasant could sell wood and charcoal except to him, but he was also free from all taxation. In the construction of the blast-furnace a very fire-resisting sandstone was employed. Most curiously this was imported from England, another proof of the close trade relations which existed between Norway and this country. The ores smelted were magnetites of varying degrees of purity. They averaged 48 to 50 per cent. of iron. They were derived from mines in the neighbourhood of Arendal, at some distance from the works. These ores, however, and a large portion of the charcoal was brought to the

works by water carriage. The ores were first calcined and then stamped small before being charged. They had fluor spar and calc spar as gangue and an additional flux was not necessary. The blast-furnaces were tapped every twelve hours. The three blast-furnaces produced between them about 1600 tons of pig iron per year. One-fifth of this was used for ordinary castings, while the remainder was converted in the hearths into wrought iron and exported to England and elsewhere.

The second largest ironworks of Norway was situate in the vicinity of the town of Moss, near Christiania. It was erected at the commencement of the eighteenth century, and at the time of Jars' visit to the proprietors was being operated by the Messrs. Anker, father and son. This firm had made an agreement with the King of Denmark, in accordance with which the works provided yearly one hundred 12-pounder cannon for the Danish fleet. In addition to cast iron guns the works produced castings of all kinds. These were made of a specially hard kind of iron. Bar iron, sheets, and nails were also made. The sheets were not beaten out under the hammer, as was then customary, but were rolled by the aid of two cast iron rollers, 2 feet long and 7 to 8 inches thick. About 150 men were employed, which, under the then existing conditions, was a considerable number. At the conclusion of the account of his Norwegian visit Jars also mentions the works at Kongsberg. Lengthy statistical details are given as to the iron trade of Norway; these include the production of iron ore for each of the years 1866–1897, and also for the year 1850, and the exports of iron ore for each of the years 1861–1898. Both these are unimportant. In 1850 Norway raised 24,000 metric tons. The maximum output was in 1872, when 32,980 tons were raised. After that the quantity dwindled, until in 1885 only 300 tons was produced. Since then there has been a slight increase. In 1897 3627 tons were raised. The statistics relating to the exports of ore show these as having of late years slightly exceeded the production. Other details show the exports to the United Kingdom and to Germany. The production of pig iron and castings in Norway in the year 1781 was 8215 metric tons. After that there was a diminution in the output, and the average for each of the years 1813 to 1817 was only 3450 tons. After that it again increased until a maximum was reached in the period 1841–1845, when the average yearly production was 10,230 tons. Since 1896 no pig iron or castings have been made. Of bar iron and steel 4160 tons were made in 1866 and 452 tons in 1897. For 1898 and 1899 no statistics are given. Details are given as to the iron trade imports and

exports. After these statistical tables the author passes to a consideration of the reasons why the iron industry of Norway has decayed. This, he thinks, has not for its cause the absence of iron ores, but the fact that Norway possesses no good coal. Although Norway is extremely rich in forests, yet the native charcoal pig iron could not compete commercially with the cheaper foreign coke pig iron. Borings for coal made in the Jäderen district, between Stavanger and Egersund, have all given unsatisfactory results. The only known occurrence of bituminous coal in Norway is on the island of Andö, the most northern of the Lofoten group. So far back as 1876 coal seams were found on the west coast of the island. Though these are not of any great size, they are said to contain a good coal and one that can easily be mined. In the years 1895 and 1896 borings made in the eastern portion of the island proved the existence of considerable deposits of gas-coal. These have a length of five and a half miles and a width of rather over three miles. They rest on granite. Quite recently much attention has been devoted in Norway to the coal deposits in Spitzbergen. According to De Geer, coal seams are found in many parts of West Spitzbergen, while F. Mewius states that this coal is in many places of very satisfactory quality, though it does not seem to occur in any very large quantities. Frequently the seams are very few in number and only a foot thick. A more thorough investigation appears, therefore, to be required before it can be ascertained whether these deposits will pay to work. If the local conditions generally do not prove too unsatisfactory, these deposits may supply the northern part of Norway. At present Norway is entirely dependent on imported coal. The imports of coal from the United Kingdom were 235,447 tons in 1870, 462,295 tons in 1880, 766,995 tons in 1890, and as much as 1,374,522 tons in 1899. The imports of coke have increased at a still greater rate. In 1880 there was imported from Germany 100 tons, while in 1899 14,414 metric tons were imported. From England the imports have been as follows :—

	Tons.
1895	48,302
1896	39,529
1897	66,566
1898	59,636
1899	70,496

While Norway is greatly lacking in coal, it possesses, on the other hand, numerous sources of water-power. Those which will be of the most importance in the near future are those that lie to the south of Dro-

theim. Quite a number, running into thousands of horse-power, are still unutilised there; but those which would yield the whole year through 10,000 horse-power or more are few in number. Indeed, the only river where the conditions are favourable enough for the utilisation of so large a horse-power is the Glommen, which rises in the neighbourhood of Köros and has a fall of 2560 metres. With its normal height of water it is capable of yielding about 300,000 effective horse-power. In 1896 a commencement was made towards the utilisation of these enormous sources of power on a larger scale than was formerly the case. Whether it will be possible in the future to utilise them for the reduction of iron seems at present very doubtful.

Dealing next with the supplies of iron ore available, the author observes that, although not exactly rich in iron ore, the country possesses some not inconsiderable deposits, especially in the Nordland district. According to Vogt, the ore deposits there may be divided into two main groups:—(1) The ores in the Dunderland Valley in Ranen, those of Näverhaugen in Salten, Tomö, &c.; and (2) the ore deposits of the Lofoten and Vesteraalen Islands and Stjernö. The first-named are usually of great length and size, but of low contents of iron. This averages only about 40 per cent., and the percentage of phosphorus is about 0·2. The ore is usually high in silica. Only the richer portions can therefore be smelted direct, while the remainder has to be enriched by magnetic methods. Some experiments have shown that the Dunderland and Näverhangen ore are readily reducible in size, and that one ton of ore yields about half a ton of washed ore, containing about 60 per cent. of iron. The Selvaag and Vesteraalen ores, which also only contain about 40 per cent. of iron, contain considerable quantities of titanium. Their gangue is basic, and it might therefore be possible to utilise them as fluxes. The author refers to a number of the deposits, quoting from accounts by H. T. Newbiggin, Vogt, Head, Bowron, &c. Attention is drawn to the Ekersund mine, where the ore is almost pure ilmenite, and contains about 40 per cent. of iron and some 40 to 42 per cent. of titanic acid. The future possibilities of the Norwegian iron industry are then further passed in review, and the possible utilisation of the considerable deposits of apatite that occur in Norway. A Swedish engineer, A. af Forselles, suggested that it might be possible so to arrange the smelting as to cause the pig iron made to be really a by-product, a phosphate slag suitable for manurial purposes being the main product. So far back as 1892 experiments in this direction were made at one of the blast-

furnaces of the Finnshütte. The results were relatively very satisfactory, despite the fact that an ordinary blast-furnace was used, with the result that phosphorus passed into the iron. More recently, experiments in this direction have been made at the Christiania steel-works. The following was the composition of the charge :—

9 kilogrammes iron scrap.
6·5 kilogrammes phosphate material from Kragerö.
1·5 kilogramme charcoal.

The fusion lasted 4 hours and 20 minutes, with the result that a slag of the following percentage composition was obtained :—

SiO_2.	$Fe_2O_3+Al_2O_3$.	CaO.	P_2O_5.
40·99	13·68	34·92	1·98

The iron then contained phosphorus equivalent to 12·80 per cent. of phosphorus, 5·26 per cent. of carbon, 0·29 of manganese, and 2·19 of silica. Another experiment with Bessemer scrap gave a slag with 13·04 per cent. of carbon, the phosphorus in the iron made being equivalent to 11·58 per cent. Other experiments yielded slags with 14·70 per cent. and 17·03 per cent. of phosphoric acid. In the latter case the phosphorus in the iron was less than one-third of that shown in the iron from Charge No. 1. The experiments were made in a graphite crucible. In conclusion, the country is too poor in coal of good quality ever to become a large iron producer; and similarly the iron ore deposits are not large enough to make it a large exporter of ore. On the other hand, it may be able to do without importing foreign iron.

O. Vogel * has received some further details from J. H. L. Vogt in reference to his article on Norway as an iron-producing country, and these he gives.

A comparative statement is published of the mining and metallurgical production of Norway during each of the years 1896, 1897, and 1898. The output of iron ore increased from 2000 metric tons in 1896 to 3627 tons in 1877, and to 4425 tons in 1898. Of pig iron 325 tons were made in 1896, 417 in 1897, and 231 in 1898; while of steel there was produced 400 tons in 1896, 452 in 1897, and 379 in 1898.†

* *Stahl und Eisen*, vol. xx. p. 1304.

† *Norges officieller Statistik*, Christiania, 1900; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlix. p. 149.

[redacted]

XVII.—*ROUMANIA.*

Petroleum Production.—The Roumanian petroleum statistics for the year ending April 1900 have been published.* The production was as follows:—

District.	Boreholes.	Wells.	Output.
			Tons.
Bacau	14	254	11,367
Dimbovitza	1	103	9,995
Prahova	84	335	197,330
Buzeu	9	77	6,059
Totals . . .	108	769	224,751

The production in previous years was as follows:—

	Tons.
1895-96	73,400
1896-97	85,000
1897-98	135,000
1898-99	182,540

In a paper on the petroleum industry of Roumania,† C. Alimanestianu and Edeleanu point out that Roumanian petroleum was known as far back as 1640. The first plant for its extraction was erected in 1857.

XVIII.—*RUSSIA.*

Coal.—The production of coal ‡ in Russia for the first half of 1900 was as follows:—

Districts.	Poods.
Donetz basin	331,000,000
Poland	121,792,260
Ural	12,593,452
Central Russia	9,113,822
Caucasus	2,085,043
Total	476,584,577

The coal raised in the Moscow district for the first eight months of 1900 was 10,254,694 poods, this being the production of nine working collieries. The total average number of workmen employed was 1867.

* *Monitorul intereselor petrolifere romine,* vol. ii. pp. 519–520.

† *Mining Journal,* vol. lxx. p. 1372.

‡ Communicated by Mr. Sergius Kern.

The total quantity of coal raised in 1900 was in round numbers 1,000,000,000 poods.

Donetz basin	700 million poods
Poland	240 ,, ,,
Other districts	60 ,, ,,

In 1900 200 million poods were imported from England, as against 210 million poods imported in 1899.

Coal and Iron Industry.—In an exhaustive paper, Neumark* deals generally with the coal and pig iron industries of Russia, and in particular of the southern portion of the country. The author points out that as in Germany, there are in Russia a number of iron and coal districts which work more or less independently of each other, and enter into mutual competition.

The Russian iron industry is, however, undoubtedly very ancient. Still one cannot speak of a true iron industry before the seventeenth century. In an old book of the year 1805, on the production of pig iron in Russia, published by a Swede named Norberg, it is stated that blast-furnaces of some size were erected in the neighbourhood of Tula about the year 1628, and that it was believed that German settlers there had had a hand in this. From Tula, that is, from the Central Russia district, the blast-furnace industry spread in the first instance to the Urals and Siberia. Peter the Great was the first to issue any laws relating to the industry. At the commencement of the last century the annual production of pig iron in Russia was about 80,000 tons. Since then it has gradually increased, but almost continuously year by year. In 1850 it was about 250,000 tons, in 1880 about twice that figure, and in 1891 above a million. From that time on the increase became very rapid, as the following statement shows :—

Year.	Pig Iron Production. Metric Tons.
1891	1,004,800
1893	1,149,010
1895	1,452,420
1897	1,880,410
1898	2,219,850
1899	2,703,890

The author gives similar details relating to each of the chief districts in Russia for each of the years 1880–1889. South Russia now pro-

* *Stahl und Eisen*, vol. xxi. pp. 62-68 and 110-122, with geological map, plate of blast-furnace sections, and 13 illustrations in the text.

duces 50 per cent. of the total production of pig iron in Russia, the Urals 27 per cent., Poland 11, and Central Russia 9. The other districts each yield about 1 per cent. or less. The coal industry has also increased with great rapidity, as the following table shows:—

Year.	Coal Production. Metric Tons.
1860	299,750
1870	694,520
1880	3,289,080
1890	6,014,630
1895	9,099,000
1899	13,104,000

South Russia in 1899 produced 64·31 per cent. of the total output of coal, and Poland 30·31 per cent. In a series of tables and diagrams the author shows the relative position occupied as producers by the various districts. The coal industry of Russia is extremely modern. Although the actual occurrence of coal has been known for a very long while, no regular coal-mining on any large scale was begun before the year 1855, when Poland and South Russia were the chief producers, and even then made scarcely 150,000 tons. It is only since that time that the Government has paid any particular attention to this industry. When it did, it caused a rapid improvement not only in Poland and South Russia, but also in Central Russia, the Ural, and the Caucasus. This development was assisted by the vicinity of large consuming districts. In the Donetz basin there were no forests at all, and coal formed the only fuel for every purpose. The neighbourhood of rich iron ore deposits led to a flourishing iron industry, and this again led to an improvement in the coal trade of the district. Despite the rapid progress the coal industry made, it did not at all satisfy the demand, nor does it do so now, for although the production has reached 13,000,000 tons, this is a very small quantity compared with the output in other countries. The United Kingdom and the United States, for instance, produce fifteen times, and Germany over ten times as much. Indeed, the Russian coal output still forms only 2 per cent. of the world's production. In the first half of 1900 the production of coal in Russia was 477,000,000 poods, or about 7,750,000 tons. The absence of adequate transport and trained miners, however, are hindrances to the industry, which can only slowly be overcome.

The pig iron industry of Central Russia is the oldest in Russia. It not only possessed good deposits of ore, but was also rich in forests, formerly extremely so. Until 1897 the blast-furnaces there used charcoal only, and

were independent, as far as their raw materials were concerned, of the other districts of Russia. Nowadays there is scarcely one-third of the forests remaining, and the rapid increase in the cost of charcoal has rendered the local conditions increasingly difficult. The iron ores smelted are brown hæmatites and spathic ores. The former, low in manganese, are found on the verge of the Devonian limestone in pocket deposits, and are readily won. The spathic ores occur in the Jurassic marl, and contain over 40 per cent. of iron. They are mined from a depth of 10 to 16 yards. The methods of mining in use are still extremely primitive. The ores are readily reducible in the furnace, and give, on account of their fairly low phosphorus contents, good foundry, forge, or open-hearth pig irons. The two chief ironworks are the blast-furnace plants at Tula and Lipetzk. Both of these use coke from the Donetz district. The former works has three blast-furnaces, of which two are in operation. These are modern, good-sized furnaces, making about 120 tons a day. Their dimensions are given. The consumption of coke is 1·3 ton per ton of pig iron made. The Lipetzk works possesses a quite modern plant, which is not even completed. It has two blast-furnaces, half as large again as those at the Tula works, each of the Lipetzk furnaces having a capacity of 21,200 cubic feet. Their dimensions are given. Each will have eight tuyeres.

The next district dealt with is the Ural. Until only a few years ago this was the chief iron district of Russia. The iron made from the magnetite of Mount Tagil was, for instance, world-renowned, and had a ready market even in England. So far back as the seventeenth century an iron industry existed in this district, but only on a very small scale. It did not really exist until the days of Peter the Great, who built the Neviansk works with the aid of a German, Wilhelm von Gennin. At the end of the eighteenth century most of the works were built that still exist in the Ural. This district has now 120 blast-furnaces, which make between them some 750,000 tons, or about 30 per cent. of the total pig iron production of Russia. The ores are chiefly brown iron ores and magnetites, which crop out in very many places. Clay ironstones occur less frequently. The magnetites occur on the western slopes of the Ural range. The chief of these, which are also among the most important that exist in the world, are:—(1) The Blagodat mountain, with 68 per cent. ores; and (2) the Wisoka mountain, some 30 miles to the south, with very good and pure ores, averaging about 66 per cent. of iron, and reaching up to 69 per cent. The ore of this mountain is worked open-cast, and is relatively easily reduced in the blast-furnace

without other additions. The numerous deposits of brown iron ore are also of much importance. They reach a thickness of over 43 yards, and when calcined the ores contain about 60 per cent. of iron. They are mined open-cast nearly everywhere, at about 2·5 to 3·5 copecks the pood, or say 3·5 to 5·0 shillings per ton. Although the Ural is thus extremely rich in iron ores, they are wanting in good deposits of coal. There are, it is true, beds of coal and of anthracite, but these are not at present of industrial importance. The true fuels of the Ural are wood and charcoal. It has been calculated that for a production of 10,000 tons of pig iron, and its further conversion into merchant iron, as much as 6,170,000 acres of forest is necessary, with the assumption that an eighty-year system of forestry is adopted. Despite this enormous requirement, the production of pig iron in the Urals is still capable of enlargement. In the European and Siberian Ural district there are 100 millions of acres of forest land, and less than 20 per cent. of this is now used for iron smelting purposes. Still, sooner or later, the ironworks will have to turn to mineral fuel instead of charcoal, and even now, in the less afforested districts, attention is being greatly directed towards the opening up of coking coal deposits by the Siberian Railway. The size and construction of the blast-furnaces at present used in the district is dependent on the character of the charcoal available. In the north, firs are the chief source of supply, while firs and birch in the central district are charred together, yielding a still better charcoal. The best charcoal is obtained in the Southern Ural district, where pine is the chief source of supply. The consequence is that in the Northern Ural the blast-furnaces are rarely higher than some 42 feet. In the Central Ural they are about 8 feet higher, and in the Southern district they may attain a height of 58 or 59 feet. Their average out-turn, taken as a whole, is about 20 tons per furnace, the maximum output being about 50 tons. The blast is usually heated to 300° or 400° C., and the consumption of charcoal is about 100 to 115 per cent. The average cost of the ton of pig iron is about £2 to £2, 14s. The author gives the following details as to cost, six cases being given in detail:—

	Copecks per Pood of Iron.
Ore	5·92 to 19·4
Charcoal	8·57 ,, 16·4
Limestone	nil ,, 0·9
Wages at furnace	1·59 ,, 2·5
Other working charges	1·63 ,, 3·6
Taxes	... 2·7
General expenses	... 5·5

The lowest cost quoted is 28·13 copecks per pood, and the highest 40·63 copecks. These correspond to about 37·2 and 53·8 shillings per ton. The lowest cost is in the case of a works using dear charcoal but cheap ore, and the highest in the case of one using very dear poor ore and cheap charcoal. The largest outputs quoted were for works where there were used (1) dear charcoal and cheap ore, and (2) both charcoal and ore were of average prices. The author gives a number of analyses of pig iron and slags. One curious point about the blast-furnaces of the Urals is, that many of them, instead of being cylindrical, are elliptical in section. This is stated to increase the production and to diminish the consumption of charcoal. The small section before the tuyeres has the further advantage of enabling a very high temperature to be produced, with the result that even the difficultly reducible magnetites can be readily reduced by the use of charcoal fuel. At Nijni-Tagilsk, too, the blast-furnaces used in the reduction of special pig irons, ferrosilicon, ferromanganese, and ferrochromium, have their hearth portions quite free. These are removable and are screwed into position again by hand. They last about a fortnight and require about twelve hours to replace when burnt out. This arrangement can, of course, only be used for small furnaces. Their output is about 90 poods of ferrosilicon, or 100 poods of ferromanganese. It has often been proposed to take the Ural ores to the Donetz basin or bring the Donetz coke to the Urals, but at present the cost of transport renders this commercially impossible, the distance being about 1250 miles.

The very rapid increase in the iron trade of South Russia has already been referred to. The main cause for this lies in the existence of the coal deposits of the Donetz basin. The area of these coal deposits is about 12,000 square miles larger than any other European coal-field. It is not rich in coal for an equal area, as Westphalia contains 4·4 times as much in the same area. The seams do not exceed 6 feet 7 inches in thickness, and rarely 5 feet. As a rule, they are about 2 feet to 2 feet 6 inches in thickness, though a seam of only 16·5 inches is also worked. The total thickness of workable coal varies from 69 to 125 feet. Sometimes the seams lie close together, at other times they are over 400 yards apart. The district is a difficult one to mine, the seams being often folded in a complicated manner as well as far apart. The Donetz basin contains all kinds of coal, from those with 40 per cent. of volatile constituents to anthracites with only 2. The Grüner table for Belgian coal does not apply to the coals of the Donetz basin, where sometimes good coke results from coals that yield as much

as 90 per cent. of coke, and from coals that yield as little as 50 to 60 per cent. The very same seams of coal also show different properties in different parts of the field. In one part the seam may contain long-flame coal, and in another a typical coking coal, and in a third a typical anthracite. Such varieties take place within a distance of under nineteen miles. It does not merely happen with a single seam of coal, but usually at the same time in a whole group of seams. A particular geological horizon does not, therefore, necessarily mean a particular kind of coal. This depends on other causes occurring subsequent to the original deposition. Another point that is notable is, that it is observed in every part of the field, that the deeper the seam from the surface the less volatile products does it yield on dry distillation. Down to a depth of 656 feet it is calculated that there are available a thousand million tons of bituminous coal, and 2·5 times this quantity of anthracite. Of the former, about one-fourth is long-flame coal, and the remainder is available for coking purposes. All sorts of coal are coked, some works employing for this purpose coals that yield from 25 to 40 per cent. of volatile products. So far, relatively little anthracite is mined. In 1898, of the 7,700,000 tons of coal and anthracite raised, only 900,000 tons were anthracite. In 1899 the quantity of coal coked was 2,000,000 tons, but of this quantity only 600,000 tons was true coking coal. In 1899 there were 135 collieries at work, with shafts down to over 1300 feet in depth. The average cost was from 4s. 6d. to 7s. per ton. The workpeople only work 240 days a year in consequence of the numerous holidays. This prevents the production being increased proportionately with the demand. The author gives a number of analyses of Russian coals and cokes. The carbon contents of the Donetz bituminous coals varies from 67 to 85, and of the anthracites from 85 to 91 per cent. The percentage of ash averages about 5, but it varies from 1·5 to over 25. The percentage of sulphur varies from 0·5 to 5, averaging 2. The ash is acid, and contains about 40 to 50 per cent. of silica, 25 of alumina, and a little lime. Five coal-washing plants were at work in 1899.

The manufacture of coke in the field has made enormous progress. In 1895, 500,000 tons of coke were made in 937 ovens; while in 1900 some 2,500,000 tons were made in about 4000 ovens. About two-thirds of the ovens in the Donetz field are of the Coppée type. Their dimensions are given. They are not arranged for the collection of the by-products, and it is only of late that this has received attention. The first of such plants, with 98 ovens, was started in 1899 at Uspensk. Others followed quickly. The quality of the coke varies remarkably, both physically

and chemically. Its high sulphur contents necessitate keeping the slag in the blast-furnace very basic, and the high contents of silica in its ash also make the furnace working more difficult.

The ores smelted in the Donetz basin, in addition to those obtained from the great Krivoi-Rog deposit, include local spathic ores and brown iron ores, and quite recently ores from the Kertsch district have been also used. The Donetz ores are on the whole of secondary importance. They contain from 35 to 45 per cent. of iron and 1 to 2 of manganese.

The author then deals at length with what he describes as at present the most important iron ore occurrence in Russia, the Krivoi-Rog. The ore averages—

Iron.	Silica.	Alumina.	Phosphorus.
60	5 to 8	1 to 2	0·014 to 0·030

with traces of sulphur. The richest ore is often of a pulverulent character.

The Crimea is believed to possess very large deposits of ore. They are found in the vicinity of the town of Kertsch, and the ore occurs so near the surface and in such quantity that it will be worked open-cast by the aid of steam-diggers. The iron contents reach up to 46 per cent. The upper and lower portions are poorest, only the central part being won. This yields ore with from 40 to 46 per cent. of iron, 0·5 to 3 per cent. of manganese, about 15 per cent. of silica, 5 to 6 of alumina, 0·1 to 0·2 of sulphur, and about 1·5 per cent. of phosphorus. The high contents of phosphorus form a very valuable addition to the contents, and will permit of a basic iron industry in South Russia. The more manganiferous portion of the ore often contains thin seams of pure manganese ore, and it is possible by selection to produce ore that will yield a pig iron of any desired composition. The author tabulates detailed statements as to the cost of production of pig iron in South Russia and Poland. Nine cases are given. In six of these the cost is from about £3, 14s. to £3, 19s. per ton, in one £2, 18s., and in two about £4, 3s. to £4, 8s. The cost of production of a spiegeleisen with 20 per cent. of manganese is placed at £6, 1s. The cheapest coke pig iron in the whole of Russia will be that made by the new works at Kertsch, where it will amount to from £2, 6s. to £2, 12s. per ton. At the present time there is one moderate sized blast-furnace at work there, the coke for which is made in 50 Coppée ovens. In addition to the iron ore deposits of South Russia, the author also deals with those of manganese, and then passes to a consideration of the iron ore and coal deposits of Poland. Up to 1884 the production of pig iron in Poland, was, he observes, relatively unimportant; but the establishment of high

ective duties so fostered the industry, that it has since made rapid ;ress. In conclusion, the author points out, that while in 1899 many consumed 0·1284 metric ton of pig iron per head of the ılation, the consumption in Russia was still only 0·0289 ton. He cipates that the price of the metal in Russia will fall before long, the relative consumption increase.

he business outlook in South Russian works at the commencement 901 was not at all encouraging.* The prices of pig iron have fallen ı 65 copecks to 50 copecks per pood. Several works are idle, and 14 t-furnaces are blown out. Last year the different Government orders ıcipally railway materials) to the works situated in South Russia ; valued at 60 million roubles. This year, 1901, the works have ernment orders for only half this amount, that is, for 30 million iles. In order to give more employment to the steelworks in Russia, Government gave orders for steel rails to the mills of South Russia. 1901, 9 million poods of steel rails are to be ordered at the price rouble 25 copecks per pood. This price is fixed for three years ıll Government orders for rails.

he Paris Exhibition induced W. de Kovalesky, of the Department ommerce and Industry, to prepare an exhaustive monograph, cover-1000 pages, on Russia at the end of the nineteenth century.†

·on Trade Statistics.—The production of pig iron in Russia in first half of 1900 was as follows, the statistics for the first half 399 being also shown : ‡—

District.	First Half of 1900.	First Half of 1899.
	Metric Tons.	Metric Tons.
South Russia	725,035	631,031
Ural	440,150	392,974
Poland	125,707	148,251
Central Russia	121,771	131,477
North Russia	18,458	16,115
South-West Russia	1,134	1,498
Totals	1,432,255	1,321,346
Siberia	...	2,447
Finland and Imperial Dominions in Siberia	...	13,115
Grand total	...	1,336,908

* ommunicated by Mr. Sergius Kern.
† n analysis of this important work is given in the *Revue Scientifique* of January 5.
‡ *tahl und Eisen*, vol. xx. p. 1237.

There has consequently been an increase in the out-turn of the six first named districts, which amounts to 110,909 tons in the six months as compared with the similar period of the preceding year. The most important of the industrial districts—South Russia and the Ural—shows the greatest increase. Poland and Central Russia have gone back, however. The cause of this, in the case of Poland, was the short supply of coal in the adjacent Silesian and Austrian coalfields and the strikes in Bohemia and Moravia, the Polish iron industry being entirely dependent on the imports of foreign coke. In Central Russia the decline has another source. Here two-thirds of the pig iron produced is made with charcoal, and the decreasing supply of wood year by year leads to increased cost of charcoal. Again, there is the strong competition of the coke pig iron from Central and South Russia to contend against. With regard to the statistics for South Russia those issued by the St. Petersburg Association of Ironmakers do not coincide with those published by the Charkow Bureau of Statistics. The former authority places the production of pig iron in South Russia in the first half of 1900 at 725,035 tons, and the latter at 739,580 tons. The latter is more likely to be accurate. On the whole, the outlook for the Russian iron trade is not unfavourable. The Manchuria line of railway will now be completed; another line about 1250 miles in length is to be built from Orenburg to Taschkend; the light rails of the Siberian railway will have to be replaced, and there is likely to be full work in all the shops constructing locomotives and railway waggons.

The position of the market for finished manufactures has also improved. The production of finished iron and steel in South Russia in the first half of 1900 amounted to 389,231 tons, of which 333,853 tons were sold, the remainder being worked up at the works themselves.

The imports of iron and iron manufactures in the first half of 1900 were much less than in the similar period of the preceding year, as will be seen from the following table:—

...	First Half of 1899.	First Half of 1900.
	Metric Tons.	Metric Tons.
Pig iron	56,100	25,442
Iron	151,574	48,918
Steel	20,557	11,558
Machines, machine parts, locomotives, and iron manufactures	99,590	75,508

The quantity of pig iron that is now imported into Russia amounts to scarcely 2 per cent. of the total consumption of pig iron in Russia. The time is certainly not far distant when Russia will require no imported iron. The case is different as regards the importation of machinery.

Production of Steel, Weld, and Ingot Iron.—A similar table to that relating to pig iron is published * showing the production of finished manufactures of steel, weld, and ingot iron in each of the iron-producing districts of Russia for each of the ten years 1890–1899. From this the following are taken :—

	1890.	1895.	1899.
	Metric Tons.	Metric Tons.	Metric Tons.
South Russia	108,800	263,800	828,000
Ural	266,900	326,100	422,900
Poland	105,300	177,200	268,400
Central Russia	112,500	129,900	187,000
North Russia	82,100	145,500	182,500
Finland	14,600	17,000	11,200
Siberia	4,300	1,500	3,000
Totals	694,500	1,061,000	1,903,000

It will be observed that South Russia in 1899 made seven and three-quarters as much again as in 1890, Poland over two and a half times. North Russia shows nearly the same rate of progress, and the Ural and Central Russia districts also show considerable progress.

Petroleum.—The total production of petroleum in the Baku district for 1900 was 600,326,000 poods. In 1899 the production reached 525,039,000 poods.†

Imports.—During the navigation of 1900, 1,639,089 tons of coal and 128,126 tons of coke were imported through St. Petersburg port. In comparison with the imports of 1890 there is a very considerable increase. The figures for 1890 were—Coal, 909,941 tons; coke, 42,472 tons. Meanwhile the imports of pig iron to the same port are decreasing. In 1900 the imports were 9080 tons against 37,906 tons in 1890.‡

* *Stahl und Eisen*, vol. xxi. p. 41.

† Communicated by Mr. Sergius Kern. ‡ *Ibid.*

The Russian imports in 1900 were as follows, in thousands of poods:—

	1900.	1899.	More or Less in 1900.
Coal	230,154	229,320	+ 834
Coke	31,865	33,192	− 1327
Ferro-manganese, Spiegeleisen	915	1,352	− 437
Pig iron	1,528	5,823	− 4295
Wrought iron—			
Round, bars, flat	2,296	7,358	− 5062
Sheets up to No. 25	1,561	5,895	− 4334
Plates	1,284	1,675	− 391
Steel—			
Round, bars, flat	793	1,660	− 867
Sheets up to No. 25	158	405	− 247
Plates	27	51	− 24
Rails	183	434	− 251
Machinery	4,971	7,059	− 2088
Locomotives	122	291	− 169
Agricultural machinery	1,097	1,139	− 42
Portable engines	370	355	+ 15
Machinery in parts	1,560	2,172	− 612

Iron and Steel Industry in the Ural.—G. Kamensky * gives some notes on the iron and steel industry in the Ural. On January 1, 1901, there were 107 active ironworks, of which 65 owned blast furnaces, in which the average fuel consumption is 0·9 ton of charcoal per ton of iron. The total production of pig iron was over 800,000 tons in 1900, of which 200,000 was sold as pig, and the rest converted into steel. The author also discusses the future of the district as regards ores and fuel.

The comparative production of pig iron in the Ural district † for the last five years was as follows:—

Sixty-five private works (fuel, charcoal) produced—

Year.	Poods.
1896	31,507,129
1897	35,871,000
1898	38,451,000
1899	39,844,000
1900	42,861,482

Nine Government works (fuel, charcoal) produced—

Year.	Poods.
1896	3,764,367
1897	4,840,348
1898	4,971,544
1899	4,877,807
1900	6,182,497

* *Iron and Coal Trades Review*, vol. lxii. pp. 239, 441.

† Communicated by Mr. Sergius Kern.

Ironworks in Siberia.—Iron ore is widely scattered in Siberia, but the deposits are not well surveyed, and only six or seven are worked to supply the five ironworks of the country. These are the Government works of Gourievski in the Kuznetsk coalfield, Tomsk, and the Petrovski works in the Transbaikal. There are three private enterprises manufacturing iron and steel in Siberia, viz., the Abakanski ironworks, situated on the Yenissei near Minusinsk; the Nikolaievsk ironworks near the confluence of the Oka and the Angara rivers, and lastly the Novo-Nikolaievsk works, located at no great distance from the preceding. The Nikolaievsk works are the largest, and the plant consists of one blast-furnace, one open-hearth furnace, one cementing furnace, five puddling furnaces, several reheating furnaces, five steam-hammers, rolling trains, &c., &c., and the management finds employment for 960 hands.*

XIX.—*SERVIA.*

Mineral Resources.—The mineral resources of Servia are described by D. J. Antoula † in the official catalogue of the exhibits in the Servian Pavilion of the Paris Exhibition.

XX.—*SPAIN.*

Mineral Statistics.—Preliminary statistics of the coal production of Spain in 1900 have been published.‡ The production of coal amounted to 2,680,193 tons, or 3 per cent. more than in 1899. The output of the various provinces was as follows:—

Provinces.	Tons.
Burgos	500
Ciudad-Real	298,410
Cordova	426,325
Gerona	31,593
Leon	265,631
Oviedo	1,425,000
Palencia	134,404
Seville	118,330

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* *Iron and Coal Trades Review*, vol. lxi. p. 1107.
† *Industrie Minère Serba*, Paris, 1900.
‡ *Revista Minera*, vol. lii. pp. 109-111.

The production of anthracite amounted to 154,336 tons, of lignite to 92,444 tons, of coke to 734,378 tons, and of briquettes to 356,167 tons.

Statistics of the iron ore production of Spain in 1900 have also been published.* The output was as follows:—

Provinces.	Tons.
Vizcaya	5,317,029
Santander	1,117,017
Murcia	686,709
Almeria and Granada	562,758
Seville	362,454
Oviedo	61,000
Malaga and Jaen	68,001
Navarre	32,702
Guipuzcoa	17,476
Lugo	104,110
Other provinces	66,429
Total	8,320,246†

The output of the two most productive companies in Bilbao was as follows:—

Ore.	Orconera.	Martinez Rivas.
Rubio and vena	922,106	578,357
Campanil	13,636	—
Calcined carbonate	76,871	2,968
Total	1,012,613	581,325

The exports of iron ore from Spain amounted to 7,823,270 tons, of which 5,484,323 tons went to Great Britain. The production of pig iron at the thirteen works in operation in Spain was 294,118 tons, and that of wrought iron and steel comprised 91,586 tons of Bessemer ingots, 59,048 tons of open-hearth ingots, 65,045 tons of puddled iron, and 212,121 tons of rolled and forged iron and steel. The exports of pig iron amounted to 27,169 tons, and the consumption of iron and steel to 249,661 tons.

On the occasion of the Paris Exhibition, the Mining Association of Bilbao prepared an exhaustive account ‡ of the progress effected in the iron mines of the province of Vizcaya from 1870 to 1899.

* *Revista Minera*, vol. lii. pp. 165–167.

† 8,480,246 in original.

‡ *Las Minas de Hierro de la Provincia de Vizcaya*, Bilbao, 1900, p. 147, with coloured geological map. A copy of this work has been presented to the Institute Library.

XXI.—*SWEDEN.*

Iron Ore.—At the beginning of December 1900 the last steamer laden with iron ore left Luleå. Altogether during the season, 1,054,675 tons of iron ore, or 30,083 tons more than in 1899, were shipped. The greater portion went to Dutch ports for the Rhenish Westphalian blast-furnaces. Next year the Kiirunavaara mines will be producing, and when the railway to the Norwegian coast is finished, as it is believed * it will be in 1903, an estimated output of 1,500,000 tons annually will be shipped from these mines.

The exports of iron ore from Sweden † in 1900 amounted to 1,619,901 tons.

XXII.—*SWITZERLAND.*

Mineral Resources.—In connection with the Paris Exhibition, a description of the mineral resources of the Canton of the Grisons ‡ was prepared. The volume, which covers 47 pages, and is illustrated by nine coloured geological sections, contains a history of the mineral output of Switzerland by P. Lorenz, and a description by C. Tarnuzzer of the iron ore deposit in the Val Sourda, between Bonaduz and Versam, and of the iron ores of the Schmorras Alp in the Val Nandro, Oberhalbstein.

XXIII.—*TURKEY.*

The Mineral Industry of Turkey.—The mineral industry of Turkey is but small. § In Asia Minor, Macedonia, and Thessaly minerals of all kinds occur in quantity, but they are but very inadequately worked. This is largely due to the want of adequate means of communication.

Chrome iron ore exists in larger quantities in Asiatic and European Turkey than it does in any other part of the world. It is mined at a number of places, the names of which are given. The most important of these mines are those of Daghardi, near Kutahia, which yield 12,000 to 15,000 tons of chrome iron ore yearly, and this formed the chief portion of the exports of this material. About equal quantities go to Germany, the United States, and the United Kingdom, and a somewhat smaller portion to France.

* *Industrie*, December 1, 1900.
† *Comité des Forges de France*, Bulletin No. 1792.
‡ *Notices sur quelques Gisements Métallifères du Canton des Grisons*, Graubünden, 1900.
§ *Stahl und Eisen*, vol. xx. pp. 1238–1239.

Manganese ore occurs near Balia, but the deposit near Kassandra, in Salonica, is richer, the ores found there averaging over 45 per cent. of manganese. These latter mines export about 45,000 tons a year. Other manganese ore concessions are mined near Smyrna, Makri, and on the Black Sea, but these only yield about 2000 tons of ore a year. Iron, nickel, and other ores are also found in quantity, and some statistics are given as to some of these.

The brown coal and coal deposits of Asia Minor are also referred to. Brown coal is found there in many places, but is only used for local purposes. The most important mine is that near Mandjilik, in the Brussa province. The lignite worked there is, however, only used for calcining purposes and for the blowing-engines at the works at Balia. For actual smelting purposes English coal is used.

There are rich deposits of coal on the northern shores of Asia Minor. The Heraclea coal has been often examined, and generally considered satisfactory. The Société d'Heraclée, which was to have opened up this deposit, is stated, however, to have lost about £800,000 in the two first years after its starting in 1896. Additional capital was subsequently raised, and the company is now stated to be in a position to ensure the regular working of the deposit. The coal seams are not very thick, and the coal from this source, for the present at least, is not likely to compete with English coal. The calorific power of the Heraclea coal is about 60 per cent. of that of English coal. The total output of all the collieries is estimated at from 360,000 to 400,000 tons.

A true iron industry does not exist in Turkey, but imported semi-manufactures are worked up in large quantities by smiths, who are very numerous—nails, horse-shoes, hoop-iron, and rough agricultural implements being made. Other iron and steel wares, the manufacture of which needs greater skill and better appliances, are only produced in Turkey on a very small scale. The imports of iron and steel manufactures into Turkey are consequently considerable. They amounted in 1899 to about 60,000 tons. Only 10 per cent. comes from the United Kingdom, by far the larger quantities coming from Belgium and Sweden. The imports from Germany are rapidly increasing. Beams form an important portion of the imports, in addition to railway material. All kinds of iron wares of common use would also find a market. These include nails, hooks, chains, cast iron wares, pipes, scythes, shovels, &c., &c. The imports of needles, cutlery, &c., are also increasing, as also are those of agricultural implements. The iron trade in Turkey is mostly in the hands of Armenian merchants, who compete greatly with one another.

XXIV.—*UNITED STATES.*

Iron Trade Statistics.—The American Iron and Steel Association * reports the production of iron and steel in the United States in 1900 to have been as follows:—

	Tons.
Pig iron	13,789,242
Bessemer steel ingots	6,684,770
Bessemer steel rails	2,361,921
Basic open-hearth steel ingots	2,547,023
Acid open-hearth steel	855,529
Total open-hearth steel	3,402,552

Iron Trade Exports.—The iron and steel exports of the United States for the year 1900 have been published.† They show a total of 1,205,964 tons, against 778,901 tons for the previous year. The exports of steel rails show an increase of over 84,000 tons compared with the corresponding period of 1899. The other prominent features of the record are an increase of 58,000 tons in pig iron, a decrease of 2000 tons in sheets and plates, and an increase of 13,470 tons in structural iron and steel. Of wire nails and spikes, the total exports for the year have decreased from 33,535 to 27,404 tons. The details are as follows:—

	1900.
Iron ore	51,460
Pig iron	286,783
Scrap	49,283
Bar iron	13,285
Bars or rods of steel other than wire	81,366
Iron rails	5,374
Steel rails	356,245
Billets, ingots, and blooms	107,476
Hoop, band, and scroll	3,021
Rods, wire, of steel	10,652
Iron sheets and plates	9,331
Steel sheets and plates	45,554
Structural iron and steel	67,714
Wire	78,014
Cut nails and spikes	11,163
Wire nails and spikes	27,404
All other nails, including tacks	1,807
Total	1,205,932

American Consumption of Pig Iron.—Statistics showing the approximate consumption of pig iron in the United States during the year 1900 have just been published by the American Iron and Steel Association.‡ The figures for 1899 are also given for comparison. The consumption of pig iron in these two years is approximately shown by

* *Bulletin of the American Iron and Steel Association*, vol. xxxv. p. 76.
† *Ibid.*, p. 22. ‡ *Ibid.*, p. 30

adding the production, imports and stocks of unsold pig iron at the beginning of each year, and subtracting from the total thus obtained the exports and unsold stocks at the close of each year, the comparatively small quantity of foreign pig iron held in bonded warehouses at the close of each year not being considered. In all the Association's calculations spiegeleisen and ferro-manganese are invariably treated as pig iron and warrant stocks are included in unsold stocks. The following table shows the approximate consumption :—

Pig Iron.	1899.	1900.
	Gross Tons.	Gross Tons.
Domestic production	13,620,703	13,789,242
Imported	40,393	52,565
Stocks unsold January 1	415,333	68,309
Total supply	14,076,429	13,910,116
Deduct stocks December 31	68,309	446,020
Also exports	228,678	286,815
Approximate consumption	13,779,442	13,177,281
Shrinkage in consumption in 1900 as compared with 1899	...	602,161

The Steel Industry.—R. H. Thurston * traces the development of the steel industry in the United States, and compares the production with that of Great Britain and of Germany. The increasing use of steel and its probable future is discussed in a popular way.

E. Phillips † contrasts English and American methods in the iron industry in respect of tin-plate bars, costs, and facilities in various directions, blast-furnaces and open-hearth furnaces.

Lake Superior Iron Ore.—H. J. Stevens ‡ reviews the first half-century of mining in the Lake Superior district, where the total of the output has now surpassed 171 million tons. The proportional shares of the various districts and of the different mines are dealt with for the period and for last year. A sixth producing range is now added for the first time, and this is the Michipicoten in Canada, while the Atikokan will soon be included as another Canadian source of ore.

According to D. E. Woodbridge,§ Lake Superior iron ore shipment for 1900 show an increase of about 1,000,000 tons over 1899. The

* *The Century Magazine*, 1901, pp. 562 568.
† *American Manufacturer*, vol. lxviii. pp. 387-391. ‡ *Ibid.*, pp. 7-9.
§ *Engineering and Mining Journal*, vol. lxxi. pp. 17-18.

increase is less than was expected, partly due to the early frost. The shipments from the various ports have been as follows :—

	1899.	1900.
	Tons.	Tons.
Two Harbours, Minnesota	3,973,733	4,007,294
Duluth, Minnesota	3,509,965	3,888,986
Escanaba, Michigan	3,720,218	3,436,734
Marquette, Michigan	2,733,596	2,661,861
Ashland, Wisconsin	2,703,447	2,633,687
Superior, Wisconsin	878,942	1,519,000
Gladstone, Michigan	381,457	418,854
Michipicoten	...	62,000
Total	17,901,358	18,628,416 *
All-rail shipments (estimated)	350,446	600,000
Grand total	18,251,804	19,232,315

Seven Lake Superior mines have shipped this year over 750,000 tons each, two have shipped over 1,000,000 tons, and the greater portion of the output has come from comparatively a few properties.

According to another estimate, the production of ore in the various ranges of the Lake Superior district was as follows : †—

	1899.	1900.
	Tons.	Tons.
Marquette	3,757,010	3,457,522
Menominee	3,301,052	3,261,221
Gogebic	2,795,856	2,875,295
Vermillion	1,771,502	1,655,820
Mesabi	6,620,384	7,809,535
Total	18,245,804‡	19,059,393

Coke.—In the Connellsville district in 1900 the number of ovens was 20,954, and the production was 10,166,234 tons, as compared with 19,689 ovens and 10,129,764 tons in the previous year. The average prices for the two years in question were 2·00 and 2·70 dollars per ton.§

Mineral Production of Iowa.—Perhaps the most important change in the mining situation in Iowa || within the year 1899 was the opening of the iron deposits near Waukon, but the conditions are not

* 18,632,315 in original.
† *Iron Trade Review*, January 31, 1901, p. 10. ‡ 18,251,804 in original.
§ *Iron Age*, January 24, 1901, p. 19.
|| "Annual Report of the Iowa Geological Survey," 1900.

yet ripe for the development of the deposits. The importance of the Waukon ore is found in the fact of the cheapness with which it can be mined and its fair quality. In connection with the activity in iron ore mining, it is interesting to note that the coal-mines of the State have had a year of unusual and welcome prosperity. Several new and important mines have been opened. Experiments seem to have demonstrated that in ovens of proper construction, certain, at least, of the Iowa coals can be coked, and arrangements are now being made to build the first battery of ovens at Des Moines.

XXV.—*COMPARATIVE TABLES.*

The World's Production of Coal and Iron.—For purposes of comparison the following summary of the production of coal in the principal countries of the world is appended :—

Country.	Year.	Production in Tons.
United Kingdom	1900	225,170,163
Australasia—		
New South Wales . . .	1900	5,507,497
New Zealand	1899	975,234
Queensland	1899	494,669
Tasmania	1899	44,141
Victoria	1899	262,380
Western Australia . . .	1899	54,336
Austria, coal	1899	11,455,139
„ lignite	1899	21,751,791
Hungary, coal	1899	1,238,855
„ lignite	1899	4,792,584
Belgium	1899	22,072,068
Borneo	1899	35,675
Bosnia	1899	303,425
Canada	1899	4,078,779
Cape Colony	1899	186,299
France	1900	33,270,385
Germany, coal	1900	109,271,726
„ lignite	1900	40,279,532
Greece	1898	17,310
Holland	1899	212,973
India	1899	4,937,160
Italy, lignite	1899	388,534
Japan	1898	6,598,033
Mexico	1899	113,191
Natal	1899	324,161
Peru	1898	10,000
Portugal, anthracite . . .	1899	11,920
„ lignite	1899	10,369
Roumania, lignite . . .	1899	78,000
Russia	1899	13,104,000
Servia	1896	11,736
South African Republic . .	1898	1,938,424
Spain	1900	2,686,133
Sweden	1899	239,344
United States	1900	238,877,182

A similar summary showing the production of pig iron is as follows:—

Country.	Year.	Production in Tons.
United Kingdom	1900	8,908,570
Austria	1899	996,385
Hungary	1899	451,637
Bosnia	1899	13,749
Belgium	1900	1,018,507
Canada	1899	94,077
France	1900	2,699,494
Germany and Luxemburg	1900	8,422,842
Italy	1898	12,387
Japan	1898	20,588
Russia	1900	2,878,000
Spain	1900	294,118
Sweden	1899	497,727
United States	1900	13,789,242

Neumark * publishes the following statement as to the production of coal, iron ore, and pig iron in different countries in the year 1898:—

Production of Coal.

	Per Cent. of World's Production.
United Kingdom	30·2
United States	29·5
Germany	19·8
Austria	5·3
France	4·9
Belgium	3·3
Russia	1·9
Other States	5·0

Production of Iron Ore.

	Per Cent. of World's Production.
United States	28·1
Germany	22·7
United Kingdom	14·7
Spain	10·1
Russia	7·0
France	6·7
Sweden	3·3
Other States	7·4

The total production of coal is placed at 663,000,000 tons, and of iron ore at 70,156,000 tons.

* *Stahl und Eisen*, vol. xxi. pp. 62–68.

Production of Pig Iron.

	Per Cent. of World's Production.
United States	34·10
United Kingdom	23·28
Germany	19·77
Russia	6·67
France	6·32
Other States	9·86

The total production of pig iron is estimated at 40,605,000 tons.

W. Fawcett gives a summary of an elaborate monograph dealing with the iron and steel trade of the United States issued by the Treasury Department Bureau of Statistics. Commenting upon the production of iron ore and coal in all countries in 1899, it is stated: "The meaning of these figures is clear; they indicate that the leadership in the production of those raw materials on which the production of iron and steel depends has not only temporarily, but permanently passed from the eastern to the western shores of the Atlantic Ocean. Nearly one-third of the world's output of iron ore entering into commercial account is now produced in the United States. This fact alone, unsupported by the existence of coal supplies on which Europe is now beginning to draw, might not imply permanent ascendency on the part of American iron-making materials, but with coal measures twelve times greater in area than those of Western Europe, it is plain that, on the basis of these two agents of development, primacy in the materials of iron and steel production has in all probability for the coming century passed to the United States. This view of the world's iron ore situation receives acceptance elsewhere than at home."

The demand for improved methods and machines has made America the foremost producer of iron and steel. Technological training of men and masters in iron-working processes has enabled Germany to rise as the worthy competitor of both Great Britain and the United States. No other single feature of German development has done so much to bring her trade to the front rank of excellence and value. The position of Great Britain is what it is to-day and what it was in the past because of her commercial genius. Prolonged leadership in trade has, however, made her lax, and caused her to lose the art of quick adaptation to changed conditions of competition. In the lessons which each of these Powers is seeking to learn from the others the three characteristic factors contain the secrets of the century's progress in the iron and steel trade—the invention of machinery and methods, the education of the

[redacted]

worker, and the cultivation of the consumer. Permanent national prosperity lies along these paths.*

World's Consumption of Coal.—The consumption of coal in the year 1899 amounted to 0·01 ton per head in India, 0·11 ton in Russia, 0·14 in Italy, 0·19 in Spain, 0·37 in Austria-Hungary, 0·53 in Sweden, 0·99 in British Colonies, 1·06 in France, 1·62 in Germany, 2·60 in the United States, 2·75 in Belgium, and 3·83 ton in the United Kingdom. France, Russia, Sweden, Spain, Italy, Austria and Hungary, Canada, Cape Colony, and Victoria consumed more coal than they produced, while in the following countries the output was in excess of the consumption :—United Kingdom, New South Wales, United States, Germany, Belgium, and Japan.†

The Railway Systems of France, Germany, and the United Kingdom.—An interesting comparative statement is published ‡ showing the present relative positions of the railway systems of the United Kingdom, France, and Germany. The persons and goods conveyed were as follows in 1898 :—

	Persons. Millions.	Goods. Tons.
United Kingdom . . .	1062·9	384·7
Germany	763·0	304·4
France	409·7	119·5

The locomotives, carriages, and goods trucks numbered as follows in 1898 :—

	Locomotives.	Carriages.	Trucks.
United Kingdom . .	19,214	45,125	690,428
Germany	17,623	35,086	383,578
France	10,650	27,634	281,043

The length of the line of rails was as follows :—

	Total Length. Kilometres.	Length in Kilometres per 10,000 Inhabitants.
United Kingdom . . .	34,849	8·63
Germany	48,280	8·88
France	41,703	10·80

* *Engineering and Mining Journal*, vol. lxx. pp. 487–489.
† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlviii. p. 637.
‡ *Stahl und Eisen*, vol. xxi. pp. 43–44.

The World's Trading Vessels.—The Bureau Veritas gives the following details as to the mercantile steamships of the different countries :—

Country.	1901.		1900.	
	No.	Registered Tonnage.	No.	Registered Tonnage.
United Kingdom	5649	11,859,581	5453	11,093,807
Germany	1031	2,169,029	900	1,873,388
United States	674	1,183,851	551	970,881
France	545	1,060,268	526	985,968
Norway	719	769,242	657	672,549
Spain	394	658,257	377	551,887
Italy	304	556,494	258	443,365
Russia	484	489,927	435	407,536
Japan	338	477,311	332	455,535
Netherlands	257	455,776	224	365,995
Denmark	335	413,134	318	388,670
Sweden	544	395,102	497	339,879
Austria-Hungary	193	389,157	167	335,314

It will be seen that the United Kingdom in 1901 possessed 54·43 per cent. of the total tonnage, and Germany 9·91 per cent.

With regard to sailing vessels, the United Kingdom again holds the premier position, the United States coming next, and then Norway, Germany being fourth on the list and Italy fifth. The figures are as follows :—

Country.	1901.		1900.	
	No.	Registered Tonnage.	No.	Registered Tonnage.
United Kingdom	7326	2,513,307	7706	2,662,168
United States	3671	1,360,978	3497	1,291,954
Norway	2123	898,761	2306	956,678
Sweden	1484	274,681	1423	277,651
Germany	955	551,025	981	548,053
Italy	1527	500,408	1557	492,188
Russia	2533	478,930	2455	473,689
France	1396	341,037	1371	309,831

The total number of sailing ships in all countries was 27,867 in 1900, and 27,982 in 1901, the tonnage being respectively 8,347,626 and 8,205,089.*

* *Stahl und Eisen*, vol. xx. pp. 1236-1237.

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